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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 5 :
C12N 15/31, 15/63, C07K 7/08
C07K 7/10, 15/00, A61K 39/102
A61K 47/48, G01N 33/569
C07H 15/08, 15/18

A2

(11) International Publication Number: **WO 93/15205**

(43) International Publication Date: 5 August 1993 (05.08.93)

(21) International Application Number: PCT/CA93/00041

(22) International Filing Date: 3 February 1993 (03.02.93)

(30) Priority data:
9202219.3 3 February 1992 (03.02.92) GB

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(81) Designated States: AU, BR, CA, FI, JP, KR, NO, RU, UA, US, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
Without international search report and to be republished upon receipt of that report.

(54) Title: SYNTHETIC HAEMOPHILUS INFLUENZAE CONJUGATE VACCINE

(57) Abstract

Synthetic peptides have an amino acid sequence corresponding to at least one antigenic determinant of at least one protein, usually a structural protein, particularly the P1, P2 and P6 protein, of *Haemophilus influenzae* (Hi), particularly type b, and are used as is, in chimeric T-B form, in lipidated form, linked to a carrier molecule, particularly a synthetic PRP molecule and/or polymerized to form molecular aggregates, in vaccines against Hi.

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TITLE OF INVENTION

SYNTHETIC HAEMOPHILUS INFLUENZAE CONJUGATE VACCINE

FIELD OF INVENTION

The present invention relates to synthetic vaccines against Haemophilus influenzae (Hi) infection. In particular, the invention relates to the use of potent T-helper cell determinants (THDs) and B-cell epitopes (BEs) of the outer membrane proteins (OMPs) P1, P2 and P6 of Hi, covalently linked to synthetic oligosaccharides containing repeating units of polyribosylribitol phosphate (sPRP) to form immunogenic synthetic PRP-peptide conjugate vaccines that can elicit high titers of anti-PRP and anti-OMP antibodies in mammals.

BACKGROUND TO THE INVENTION

Haemophilus influenzae type b (Hib) is a major cause of bacterial meningitis in children under five years of age (refs. 1, 2). The literature references are identified at the end of this disclosure). The bacterium is protected from phagocytosis by a polysaccharide capsule that is a repeating polymer of polyribosyl ribitol phosphate (PRP). Antibodies induced against the capsular polysaccharide of the organism are protective (ref. 3). Effective conjugate vaccines in which PRP is linked to different carrier proteins such as diphtheria toxoid (PRP-D), tetanus toxoid (PRP-T), CRM 197 (HbOC) and the outer membrane protein of Neisseria meningitidis have been developed (refs. 4, 5). However, these conjugate vaccines do not protect against other invasive encapsulated H. influenzae type a and c strains and, more importantly, against non-encapsulated non-typeable H. influenzae strains that are one of the common causes of otitis media for which there is no vaccine. Therefore, the inclusion of selected non-encapsulated H. influenzae immunogens in current Hib vaccines is necessary to develop a universal Hi vaccine.

Granoff and Munson (ref. 6) have reported that antibodies directed against Hib outer membrane proteins (OMP) P1, P2 and P6 were protective in the infant rat model of bacteremia. Therefore, a promising strategy for designing a universal H. influenzae vaccine with enhanced protective ability would be to use either purified OMPs or their protective epitopes as additional immunogens and carriers for PRP. The gene coding for P1 has been cloned from several different Hib subtypes (refs. 7, 8). The comparative analysis of P1 protein sequences from these Hib isolates revealed the existence of three hypervariable regions. Indeed, the P1-specific MAbs reported by Hansen's group recognize only 50% of the Hib isolates tested (refs. 7, 9). For the P2 protein, although the nucleotide sequences of the P2 gene isolated from two different Hib subtypes (1H and 3L) were found to be identical (refs. 10, 11), some amino acid variability was found among the P2 sequences of two other Hib subtypes (2L and 6U) (ref. 11). In contrast, analysis of antigenic determinants, gene sequences and restriction fragment length polymorphisms experiments indicated that the P6 protein was highly conserved among all strains of Hi (ref. 12).

Recent studies showed that a murine P1-specific monoclonal antibody (MAb 7C8) and rabbit antisera raised against purified P1 from either typeable or non-typeable H. influenzae strains were protective in animal models (refs. 9, 13, 14). Murphy and Bartos (ref. 15) also reported that a monoclonal antibody recognizing a surface-exposed epitope of a non-typeable H. influenzae P2 protein had bactericidal activity in vitro. Anti-P1 and anti-P2 monoclonal antibodies were found to cross-react with typeable and non-typeable strains of H. influenzae (refs. 16 to 18). However, there are still serious concerns with the use of whole native Hib OMPs as an efficacious universal vaccine against both typeable

and non-typeable Hi. Firstly, children who recover from otitis media caused by non-typeable Hi generally develop bactericidal antibodies against variable antigens, such as P2 and lipooligosaccharides. Secondly, the P1 and P2 cross-protective epitopes described above have not yet been identified. Thirdly, it was reported (ref. 12) that the epitope(s) recognized by anti-P6 bactericidal antibodies are expressed in small amounts on the bacterial surface, and recurrent infections may thus be possible. Fourthly, little is known about the role of cellular immune responses to against OMPs. The immunodominant T-helper cell epitopes of Hi OMPs have not been characterized. Therefore, the identification of the functional T-helper cell epitopes and the conserved, surface-exposed and/or protective B-cell epitopes of the P1, P2 and P6 proteins is necessary to determine whether these epitopes can elicit immune responses against Hi infection.

Methods for inducing immunity against disease are constantly improving and the current trend is to use smaller and well defined materials as antigens. The objective is to eliminate the potential side-effects of certain native immunogens, while preserving their immunogenicity and ability to confer protection against disease. Recent studies have indicated that immunization of experimental animals with synthetic peptides representing specific regions of viral or bacterial proteins can induce immune responses against the parent proteins, and neutralize their biological functions (refs. 19 to 22). Thus, synthetic peptides are potential candidate antigens for the production of inexpensive and safe vaccines against infectious diseases. Recent progress in fundamental immunology has revealed that good and effective immunogens should contain two distinct functional antigenic determinants (epitopes). One epitope (T-cell epitope) is designed to be presented in

the appropriate MHC class II antigen context to the immune system and induce T-helper cell activity. The other epitope (B-cell epitope) must be recognized by a cognate B-cell antigen receptor to elicit antibody production (refs. 23 to 26). Therefore, in order to produce a potent and efficacious synthetic vaccine, both functional T-helper and B-cell epitopes must be included in the synthetic construct.

Synthetic PRP dimer, trimer and tetramer have been synthesized, purified and conjugated to carrier proteins for animal immunogenicity studies (refs. 27, 28). These studies showed that synthetic PRP trimer-protein conjugates in the presence of strong adjuvants such as complete Freund's adjuvant (CFA) could elicit anti-PRP antibody responses in experimental animals.

Instead of using conventional heterologous carrier proteins, our strategy utilizes synthetic peptides containing immunodominant epitopes from Hi OMPs as additional antigens and as carriers for PRP to develop the first generation of fully synthetic PRP-peptide conjugate vaccines with enhanced protective ability and autologous T-cell priming. Such vaccines also have other potential advantages over the existing vaccines in which PRP is conjugated to a foreign protein (diphtheria toxoid (PRP-D), or tetanus toxoid (PRP-T), or CRM197 (HbOC), or OMP of Neisseria meningitidis). Firstly, the use of synthetic Hi vaccines should help reduce the amount of D or T in any future multivalent combined vaccines, thus minimizing the potential risk of hyperimmunization against these carrier proteins. Secondly, PRP may be coupled to a conserved protective epitope to produce a vaccine against both invasive Hi disease and otitis media.

ABBREVIATIONS AND DEFINITIONS

CRM_{197} a non-toxic protein antigenically cross-reactive with diphtheria toxin

Hi	Haemophilus influenzae
Hib	Haemophilus influenzae type B
MAP	multiple antigen peptide
MBS	m-maleimidobenzoyl-N-hydroxysuccinimide
OMP	outer membrane protein
PEG	polyethylene glycol monomethyl ether
PRP	polyriboseribitol phosphate

ASPECTS OF THE INVENTION

One aspect of the present invention is directed towards the provision of immunogenic synthetic conjugate vaccines comprising synthetic PRP oligomers and antigenic determinants of Hi outer membrane proteins.

The present invention, in another aspect, is directed towards the provision of synthetic PRP-peptide conjugate vaccines comprising a defined length of synthetic PRP oligomers.

A further aspect of the present invention is directed towards the provision of a chemical process that efficiently produces synthetic PRP with chemically reactive functional groups allowing for their site-directed conjugation to an antigenic determinant of Hi outer membrane proteins, using polyethylene glycol monomethyl ether (PEG) as solid support.

The present invention, in a yet further aspect of the invention is directed towards the provision of a method which can be used to optimize the immunogenicity of the synthetic PRP-peptide conjugates, selecting the correct orientation of sugar moieties with respect to the T-cell epitope.

An additional aspect of the present invention is directed towards the provision of a chemical process that can enhance the immunogenicity of carbohydrates, using multiple antigen peptide system (MAPs) containing antigenic determinants of Hib as carriers to increase the density of carbohydrate moeities in synthetic PRP-peptide conjugates.

The present invention, in yet an additional aspect, is directed towards the provision of a universal Hi vaccine comprising immunogenic synthetic PRP-peptide conjugates and cross-protective Hi antigens.

A yet another aspect of the present invention is directed towards the provision of a new generation of polyvalent vaccines comprising immunogenic synthetic PRP-peptide conjugates, and Hi antigens combined with other vaccines, such as DTP-polio, Neisseria meningitidis serotype A, B, C, abd W, and S. pneumoniae serotype 6B, 14, 19F and 23F.

The present invention, in a further aspect, is directed towards the provision of a synthetic PRP-peptide conjugate that can be used in a diagnostic immunoassay to detect the presence of anti-Hib antibodies, for example, anti-PRP and anti-OMP antibodies.

A yet further apsect of the present invention is directed towards the provision of a mixture of PRP-specific and OMP-specific antibodies as a component in a diagnostic immunoassay kit to detect the presence of typeable or non-typeable Hi strains in biological specimens.

SUMMARY OF INVENTION

The present invention relates to the provision of immunogens and candidate vaccines made of peptides containing the amino acid sequences of various antigenic determinants (T-helper cell and B-cell epitopes) of the outer membrane proteins (P1, P2 and P6) of Hib. Synthetic vaccines comprising one or more of these peptides that can be adminstrated either as free peptides, or covalently coupled to synthetic PRP oligomers as synthetic glycoconjugate vaccines and/or linked to a lipidic moiety to enhance their immunogenicity, are disclosed.

In one aspect of the present invention, there is provided a synthetic peptide having an amino acid

sequence corresponding to at least one antigenic determinant of at least one protein of Haemophilus influenzae, preferably an outer membrane protein of Haemophilus influenzae type b.

In one embodiment, the present invention comprises an essentially pure form of peptide containing at least one amino acid sequence corresponding to a conserved antigenic determinant of the Hi P1 protein, which peptide is capable of eliciting polyclonal antibodies in mammals that can recognize Hi in vitro. These P1-specific polyclonal antibodies can be used as a component of test kits for detecting the presence of Hi in a biological sample. The peptides can have, for example, the amino acid sequences corresponding to amino acids 1 to 29, 39 to 64, 103 to 137, 165 to 193, 189 to 218, 226 to 253, 248 to 283, 307 to 331, 400 to 437 and 179 to 218 of the mature P1 protein of Hib MinnA strain, respectively, as set forth in Table 1 below (SEQ ID NOS: 1, 12, 3, 4, 5, 6, 7, 9, 13 or 14 and 15 respectively) or any portion or variant thereof which retains immunogenicity.

In another embodiment, the present invention comprises an essentially pure form of peptide containing at least one amino acid sequence corresponding to a conserved antigenic determinant of the P2 protein, which peptide is capable of eliciting polyclonal antibodies in mammals that can recognize Hi in vitro. These P2-specific polyclonal antibodies can be used as a component of test kits for detecting the presence of Hi in biological samples. The peptides can have, for example, the amino acid sequences corresponding to amino acids 1 to 14, 125 to 150, 241 to 265, 263 to 289, 285 to 306, 302 to 319, and 314 to 341 of the mature P2 protein of the Hib MinnA strain, respectively, as set forth in Table 2 below (SEQ ID NOS: 16, 23, 28, 29, 30, 31 and 32 respectively) or any portion or variant thereof which retains immunogenicity.

In another embodiment, the present invention comprises an essentially pure form of peptide containing at least one amino acid sequence corresponding to an antigenic determinant of the P6 protein, which peptide is capable of eliciting polyclonal antibodies against Hi in mammals. These P6-specific polyclonal antibodies should be useful in test kits for detecting the presence of Hi in any biological sample. The peptides can have, for example, the amino acid sequences corresponding to amino acids 1 to 22, 19 to 41, 35 to 58, 54 to 77, 73 to 96, 90 to 114 and 109 to 134 of the mature P6 protein of the Hib MinnA strain, respectively, as set forth in Table 3 below (SEQ ID NOS: 35 to 41 respectively) or any portion or variant thereof which retains immunogenicity.

In another embodiment, the present invention comprises at least one P1 peptide that contain at least one amino acid sequence corresponding to an immunodominant linear B-cell epitope of the P1 protein. These epitopes can be used as target antigens in diagnostic kits to detect the presence of anti-Hi antibodies for example, protective antibodies. The peptides can have, for example, the amino acid sequence corresponding to amino acids 39 to 64, 103 to 137, 165 to 193, 248 to 283, 307 to 331, 400 to 437 and 179 to 218 of the mature P1 protein of the Hib MinnA strain, respectively, as set forth in Table 1 below (SEQ ID NOS: 12, 3, 4, 7, 9, 13 or 14 and 15 respectively) or any portion or variant thereof which retains immunogenicity.

In another embodiment, the present invention comprises at least one P2 peptide that contains at least one amino acid sequence corresponding to an immunodominant linear B-cell epitope of P2. These epitopes can be used as target antigens in diagnostic kits to detect the presence of anti-Hi antibodies for example, protective antibodies. The peptides can have, for example, the amino acid sequences corresponding to

amino acids 53 to 81, 148 to 174, 241 to 265 and 314 to 342 of the mature P2 protein of the Hib MinnA strain, respectively, as set forth in Table 2 below (SEQ ID NOS: 20, 24, 28 and 32 respectively) or any portion or variant thereof which retains immunogenicity.

In another embodiment, the present invention comprises at least one P6 peptide that contain at least one amino acid sequence corresponding to an immunodominant linear B-cell epitope of P6. These epitopes can be used as target antigens in diagnostic kits to detect the presence of anti-Hi antibodies for example, protective antibodies. The peptides can have, for example, the amino acid sequences corresponding to amino acids 73 to 96, 90 to 114 and 109 to 134 of the mature P6 protein of the Hib MinnA strain, respectively, as set forth in Table 3 below (SEQ ID NOS: 39, 40 and 41 respectively), or any portion or variant thereof which retains immunogenicity.

In another embodiment, the present invention comprises peptides that have been identified as immunodominant T-cell epitopes of P1. These peptides can be used as autologous carriers for PRP, or as carriers for autologous and heterologous B-cell epitopes. The peptides can have, for example, the amino acid sequence corresponding to amino acids 39 to 64, 226 to 253, 339 to 370 and 400 to 437 of the mature P1 protein of the Hib MinnA strain, respectively, as set forth in Table 1 below (SEQ ID NOS: 12, 6, 10 and 13 or 14 respectively), or any portion or variant thereof which retains immunogenicity.

In another embodiment, the present invention comprises peptides that have been identified as immunodominant T-cell epitopes of P2. These peptides can be used as autologous carriers for PRP, or as carriers for autologous and heterologous B-cell epitopes. The peptides can have, for example, the amino acid sequences corresponding to amino acids 125 to 150, 193 to 219, 219

to 244 and 241 to 265 of the mature P2 protein of the Hib MinnA strain, respectively, as set forth in Table 2 below (SEQ ID NOS: 26, 27 and 28 respectively), or any portion or variant thereof which retains immunogenicity.

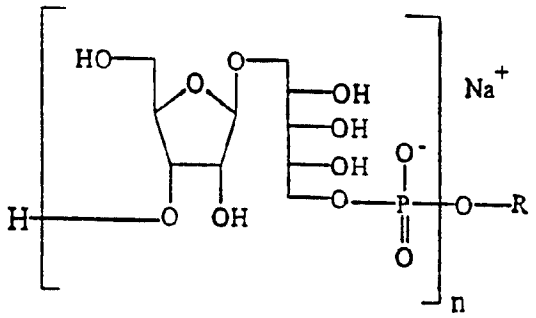
In another embodiment, the present invention comprises peptides that have been identified as immunodominant T-cell epitopes of P6. These peptides can be used as autologous carriers for PRP, or as carriers for autologous and heterologous B-cell epitopes. The peptides can have, for example, the amino acid sequences corresponding to amino acids 19 to 41, 35 to 58, 73 to 96 and 109 to 134 of the mature P6 protein of the Hib MinnA strain, respectively, as set forth in Table 3 below (SEQ ID NOS: 36, 37, 39 and 41 respectively), or any portion or variant thereof which retains immunogenicity.

In another aspect, therefore, the present invention provides an immunogenic conjugate, comprising a synthetic peptide having an amino acid sequence corresponding to at least one immunodominant T-cell epitope of at least one protein of Haemophilus influenzae linked to at least one synthetic B-cell epitope.

In another aspect of the present invention, there is provided a highly efficient chemical synthesis process to prepare synthetic PRP oligomers. This process was a combination of solid/liquid-phase synthesis using polyethylene glycol monomethyl ether (PEG) as solid support. The solid-phase support contains high number of chemically reactive functional groups ranging from about 200 to 500 μmol/g of support, as compared to the about 30 to 35 μmoles of reactive groups per g of conventional supports, such as controlled pore glass. Only stoichiometric amounts of synthetic PRP repeating unit in each coupling cycle, as compared to a 5 to 10 fold molar excess in the conventional solid-phase synthesis. In addition, the present novel process is fast, cost-effective and simple to scale-up for commercial

applications, in contrast to solution-phase synthesis which is labourious, expensive and time-consuming.

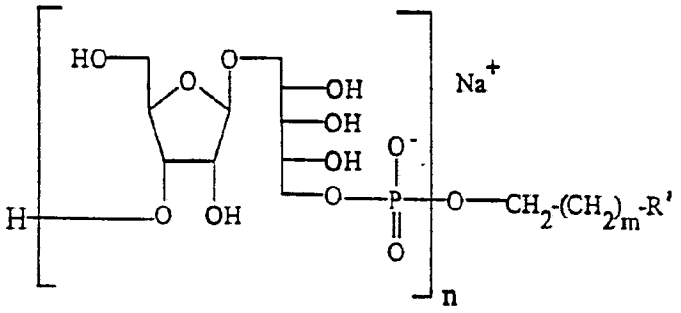
The product of this process aspect of the invention comprises a chemically reactive synthetic PRP oligosaccharide represented by the following formula:



where n is an integer, preferably from 3 to 20, and R is a linker fragment defined by $-CH_2-(CH_2)_m-X$, wherein m is an integer, preferably from 3 to 5, inclusive, and X is a chemically reactive functional group, such as $-CH_2NH_2$, $-CH_2SH$, or an amino-reactive group, such as an halogen, methanesulfonyl, trifluoromethanesulfonyl, or toluenesulfonyl, and the like, or a photoactivatable group, such as phenyl azide, nitrophenyl, benzylphenyl, and the like. The reactive functional group permits the synthetic PRP to be linked to other molecules.

In a further aspect of the invention, there is provided an immunogenic conjugate, comprising a synthetic carbohydrate antigen linked to at least one synthetic T-cell epitope. The carbohydrate antigen may be derived from bacterial material, particularly a synthetic riboseribitol phosphate (PRP) oligomer.

In yet another embodiment, the present invention provides an immunogenic synthetic PRP-peptide conjugate vaccine, that is capable of inducing high titer of anti-PRP antibodies in mammals. The synthetic PRP-carrier conjugate vaccine contains a molecule of the formula:



wherein n and m are as defined above and R' is a synthetic peptide containing at least one T-helper cell epitope, for example, a human T-cell epitope containing the amino acid sequence GPKEPFRDYVDRFYK (SEQ ID NO: 50) from the HIV-1 gag protein p24, or a T-cell epitope from Hi OMP. The carrier may be a peptide containing both a T-helper and B-cell epitopes.

In another embodiment, the present invention comprises an immunogenic synthetic glycoconjugate of a synthetic PRP oligomer of defined length and the Hib P1 peptide containing T- and/or T-B epitopes. The size of the synthetic PRP oligomer is at least three repeating units of PRP, but preferably six PRP repeating units. The peptides can have, for example, the amino acid sequences corresponding to amino acids 39 to 64, 165 to 193, 189 to 218, 226 to 253, 339 to 370 and 400 to 437 of the P1 protein of the Hib MinnA strain, respectively,as set forth in Table 1 below (SEQ ID NOS: 12, 4, 5, 6, 10 and 13 or 14 respectively), or any portion or variant thereof which retains immunogenicity.

In another embodiment, the present invention comprises an immunogenic synthetic glycoconjugate of a synthetic PRP oligomer of defined length and a P2 peptide containing T- and/or T-B epitopes. The size of the synthetic PRP oligomer is at least three repeating units of PRP, but preferably six PRP repeating units. The peptides can have, for example, the amino acid sequences corresponding to amino acids 125 to 150, 193 to 219, 219

to 244 and 241 to 265 of the mature P2 protein of the Hib MinnA strain, respectively, as set forth in Table 2 below (SEQ ID NOS: 23, 26, 27 and 28 respectively), or any portion or variant thereof which retains immunogenicity.

In another embodiment, the present invention comprises an immunogenic synthetic glycoconjugate of a synthetic PRP oligomer of defined length and a P6 peptide containing T- and/or T-B epitopes. The size of the synthetic PRP oligomer is at least three repeating units of PRP, but preferably six PRP repeating units. The peptides can have, for example, the amino acid sequences corresponding to amino acids 19 to 41, 35 to 58, 73 to 96 and 109 to 134 of the mature P6 protein of the Hib MinnA strain, respectively, as set forth in Table 3 (SEQ ID NOS: 36, 37, 39 and 41), or any portion or variant thereof which retains immunogenicity.

In another embodiment, the present invention provides the concept that the immunogenicity of a carbohydrate antigen, for example synthetic PRP, can be enhanced using a multiple antigen peptide system (MAPs) containing functional T-helper cell epitopes as carrier to increase the carbohydrate density within the synthetic glycopeptide conjugate. The MAPs can contain, for example (Fig. 1), the sequence DIVAKIAYGRTNYKYNESDEHKQQLNG (SEQ ID NO: 26) corresponding to amino acid 193-219 of the P2 protein of the Hib MinnA strain, or any portion thereof.

In another embodiment, the present invention comprises a synthetic PRP-lipopeptide (or a mixture of synthetic PRP-lipopeptides) conjugate that is capable of inducing cell-mediated and humoral immune responses against Hi in mammals. The lipopeptide can have, for example, the sequence Tripalmityl-CSSYAKAQVERNAGLIADSVKDNQITSALSTQC (SEQ ID NO: 43), corresponding to amino acids 165 to 193 of the P1 protein of the Hib MinnA strain, or any portion thereof.

In another embodiment, the present invention comprises immunogenic chimeric peptide vaccines that consist of identified T-B epitopes of either Hib P1 or P2 or P6, and can be used to immunize mammals against Hi infection. The peptides can have, for example, the sequences VKTIGDKRTLTLNTCARTRTTETGKGVKTEKEKSVGVGLRVYF (SEQ ID NO: 42), VKTIGDKNTLTLNTFGDGFYAQGYLETRFVTKASENGSNFGDC (SEQ ID NO: 43), VKTIGDKNTLTLNTCGANYLLAQKREGAKGENKRPNDKAGEV (SEQ ID NO: 44), VKTIGDKRTLTLNTDIVAKIAYGRTNYKYNESDEHKQQLNGC (SEQ ID NO: 45), VKTIGDKRTLTLNTYAKTKNYKIKHEKRYFVSPGFQYELC (SEQ ID NO: 46), GYLETRFVTKASENGSDFKEVKTIGDKRTLTLNTTANYTSQAHANLYGLNLNYSF (SEQ ID NO: 47), AKGENKRPNDKAGEVFKEVKTIGDKRTLTLNTTANYTSQAHANLYGLNLNYSF (SEQ ID NO: 48) and ARTRTTETGKGVKTEKFKEVKTIGDKRTLTLNTTANYTSQAHANLYGLNLNYSF (SEQ ID NO: 49) or any portion or variant thereof which retains immunogenicity. Peptides of the invention can also have sequence corresponding to the analogous regions of Hi isolates other than MinnA.

The novel synthetic peptides and conjugates provided herein may be formulated into a vaccine against disease caused by a pathogen, particularly Haemophilus influenzae, comprising at least one synthetic peptide and/or at least one synthetic conjugate, as described herein, and a physiological carrier therefor. The vaccine may be used for immunizing a host against the pathogenic disease by administering to a host an effective amount of the vaccine.

The vaccine may further comprise at least one other immunogenic and/or immunostimulating molecule. The invention also includes a method of immunizing a host against Hi infection, by administering to the host an effective amount of the vaccine.

Peptides described in the invention can be further either modified with lipids as lipopeptides or linked to synthetic PRP (and/or polymerized) as synthetic lipoglycopeptide conjugates to produce alternate vaccines.

The vaccines can be used to immunize against Hi infection when administered to mammals, for example, by the intramuscular or parenteral route, or when delivered to the mucosal surface using microparticles, capsules, liposomes and targeting molecules, such as toxins and antibodies.

The present invention further includes a live vector for antigen delivery containing a gene coding for an amino acid sequence of any of the synthetic peptides provided herein. The live vector may be a viral vector, such as poxviral, adenoviral, polioviral and retroviral viral vector. The live vector may be a bacterial vector, such as salmonella and mycobacteria. The live vector may be incorporated into a vaccine comprising the same and a physiologically-acceptable carrier.

As noted earlier, the synthetic peptides provided herein may be used as diagnostic reagents in a method of detecting infection by Haemophilus influenzae. Antibodies raised against any of the synthetic peptide and conjugates described herein are included in the present invention.

BRIEF DESCRIPTION OF FIGURES

Figure 1 shows the amino acid sequences of peptide carriers used in synthetic PRP-peptide conjugates studies reported herein. With respect to this Figure, the synthetic peptides identified therein have the following SEQ ID NOS:

Peptide	SEQ ID NO:
HIBP1-4	51
CHIBP1-4	52
COMP2-8	53
MAP(COMP2-8)	54
CP6-6	55
PZ4EC	56

Figure 2 shows the predictive structure of the OMP P1 by conventional structural analysis algorithms.

Hydrophilicity plots predicted by Hopp (ref. 30). The values are derived from the average of heptapeptide windows and are plotted at the midpoint of each segment;

Figures 3 and 4 show respectively, the predictive structure of the OMP P2 and P6by conventional structural analysis algorithms. The upper panel, secondary structure analysis of the local average α-helix and β-turn potentials according to Chou and Fasman (ref. 29). The lower panel, hydrophilicity plots predicted by Hopp and Woods (ref. 30). The values are derived from the average of heptapeptide windows and are plotted at the midpoint of each segment;

Figure 5 contains a diagrammatic representation of the immunodominant B- and T-cell epitopes of Hib OMP P1;

Figure 6 contains a diagrammatic representation of the immunodominant B- and T-cell epitopes of Hib OMP P2;

Figure 7 contains a diagrammatic representation of the immunodominant B- and T-cell epitopes of Hib OMP P6;

Figure 8 shows P6 peptides ELISA reactivity with guinea pig, rat and rabbit anti-P6 antisera;

Figure 9 shows P1 peptides ELISA reactivity with three human convalescent sera;

Figure 10 shows P2 peptides ELISA reactivity with three human convalescent sera;

Figure 11 shows the proliferative response of P1-specific murine T-cell lines to P1 peptides with the immunodominant T-cell epitopes highlighted with an asterisk;

Figure 12 shows the proliferative response of P1-specific murine T-cell lines to P1 peptides with the immunodominant T-cell epitopes highlighted with an asterisk;

Figure 13 contains 1 flow chart of PRP synthesis using PEG as solid support;

Figure 14 contains a flow chart of the synthesis of PRP intermediates. Bz, benzyl; Ac, acetyl; ETS,

ethylthio; Me, methyl; Allyl, allyl; DMT, 4,4'-dimethoxyltrityl; NCE, cyanoethyl; MMT, 4-methoxytrityl;

Figure 15 shows the rabbit immune response to synthetic PRP dimer and trimer conjugated to tetanus toxoid;

Figure 16 shows the rabbit immune response to different types of PRP-carrier conjugates; and

Figure 17 shows the rabbit immune response to different types of synthetic pentamer and hexamer to HibP1-4 and MAP of OMP.

DETAILED DESCRIPTION OF THE INVENTION

The present invention relates to the identification of immunogenic epitopes of Hib OMPs, novel synthetic PRP-peptide conjugates and vaccines made therefrom. These novel immunogenic agents are prepared by chemically synthesizing peptides sharing antigenic determinants with the Hib OMPs P1, P2 and P6. The peptides or lipopeptides are used either individually or linked to synthetic PRP oligomers as vaccines. They can also be polymerized to produce alternative vaccines. These vaccines can be used to immunize against Hi infection when administered to mammals, for example, by the intramuscular or parenteral route, or when delivered to the mucosal surface using microparticles, capsules, liposomes and targeting molecules, such as toxins and antibodies.

Reference will now be made in detail to the presently preferred embodiments of the invention, which together with the following Examples, serve to explain the principle of the invention. For clarity of disclosure, and not by way of limitation, the detailed description of the invention is divided into the following sections:

(i) Epitope Prediction and Peptide Synthesis;

(ii) Identification and Characterization of Immunodominant B-cell epitopes of Hi OMPs P1, P2 and P6 Using Synthetic Peptides;

(iii) Identification and Characterization of Immunodominant T-cell epitopes of Hi OMPs P1, P2 and P6 Using Synthetic Peptides;

(iv) Immunogenicity of Hib OMPs Peptides;

(v) Solid-phase Carbohydrate Synthesis of PRP Oligomers using PEG as Support;

(vi) Conjugation of synthetic PRP Oligomers to Hib OMP Peptides and Immunochemical Characterization of the Glycoconjugates; and

(vii) Utility of Hi Synthetic PRP-peptide Conjugate Vaccines.

Epitope Prediction and Peptide Synthesis

To map the immunodominant T-cell or B-cell epitopes of Hi OMPs, 13, 17 and 7 overlapping synthetic peptides covering most of the P1, P2 and P6 protein sequences (Tables 1, 2 and 3 below), respectively were synthesized using the t-Boc solid-phase peptide synthesis as described in detail in Example 12 below. The length of the peptides was chosen based on the high index of hydrophilic β-turns estimated by secondary structure prediction analysis according to conventional algorithms (refs. 29 to 31) (Figs. 2, 3, and 4). Such peptides are likely to be surface-exposed and antigenic. Peptides more than 25 residues in length were selected to better mimic native epitopes as suggested by the work of Van Regenmortel (ref. 32). Occasionally an additional cysteine residue was added to either the N-terminal or the C-terminal end of the peptides for site-specific conjugation purposes.

Identification and Characterization of immunodominant epitopes of Hi OMPs P1, P2 and P6 using synthetic peptides

To identify the immunodominant B-cell epitopes of Hib OMPs, rabbits, guinea pigs, and mice of different haplotypes (H-2^a, H-2^b, H-2^d, H-2^k, H-2^q, and H-2^s) were immunized with either purified P1, P2 or P6 proteins in

the presence of Freund's adjuvant. After both primary and secondary immunizations, all animals mounted a strong and specific anti-OMP antibody response as judged by P1-, P2- and P6-specific ELISA (Tables 4, 5 and 6 below) and immunoblot analysis. As previously reported by Granoff and Munson (ref. 6), rabbit anti-P1, anti-P2 and anti-P6 antisera consistently protected infant rats against live Hib challenge. The guinea pig anti-P2 antisera were also protective in this model.

To map the linear B-cell epitopes of Hib OMPs, overlapping synthetic peptides covering most of the sequences of P1, P2 and P6 were individually coated onto ELISA plates and probed with the various anti-P1, anti-P2 and anti-P6 antisera as described in Example 17 below. The results are summarized in Figures 5, 6, and 7. The immunodominant linear B-cell epitopes of P1 were found to be located within the peptide sequences corresponding to amino acids 39 to 64, 103 to 137, 165 to 193, 248 to 283, 307 to 331, 400 to 437 and 179 to 218 of the mature P1 protein of the Hib MinnA strain (see Table 1, below). The P2 peptides containing immunodominant B-cell epitopes were identified as residues 53 to 81, 148 to 174, 241 to 265 and 314 to 342 of the mature P2 protein of the Hib MinnA strain (see Table 2 below). Similary, the P6 peptides containing immunodominant B-cell epitopes were residues 73 to 96, 90 to 114 and 109 to 134 of the mature P6 protein of the Hib MinnA strain (see Table 3 below) (Fig. 8). Interestingly, three human convalescent sera also reacted strongly with the P1 and P2 immunodominant epitopes described above (Figs. 9 and 10). In addition, a strain-specific P1 protective B-cell epitope was mapped to a region corresponding to residues 165-193 of the P1 protein. These results indicate that the B-cell epitopes described above can be used as target antigens in diagnostic kits to detect the presence of anti-Hi antibodies in biological fluids.

Identification and Characterization of Immunodominant T-cell epitopes of Hi OMPs P1, P2 and P6 using Synthetic Peptides

The Hib OMPs-specific T-cell epitopes were determined using P1, P2 and P6 peptides and T-cell lines obtained from a panel of different strains of mice immunized with native OMPs. The lymphocyte proliferative responses of the OMP-specific T-cell lines to overlapping P1 peptides (13 peptides), P2 peptides (17 peptides) and P6 peptides (7 peptides) were determined in conventional proliferation assays as described in Example 19 below. The results (Figs. 11 and 12 and Table 7 below) revealed that certain synthetic peptides only elicited proliferative responses, and that the recognition of T-cell epitopes was MHC-restricted. Synthetic peptides corresponding to residues 39 to 64, 226 to 253, 339 to 370 and 400 to 437 of P1; residues 125 to 150, 193 to 219, 219 to 244 and 241 to 264 of P2; residues 19 to 41, 35 to 58, 73 to 96 and 109 to 134 of P6, when presented in the appropriate murine MHC context, were shown to be highly stimulatory for their corresponding OMP-specific murine T-cell lines. Therefore, these immunodominant T-cell epitopes can be used as autologous carriers for PRP, and/or OMP B-cell epitopes to enhance their immunogenicity.

Immunogenicity of Hib OMPs Peptides

To determine whether synthetic OMP peptides were possible vaccine candidates, free peptides and peptide-KLH conjugates were assessed individually for their immunogenicity. Rabbit anti-peptide antisera were tested for their reactivity with the immunizing peptides and their parental proteins by ELISA and immunoblotting. As shown in Table 8 below, all anti-P1 peptide antisera except those raised against HIBP1-8 or HIBP1-8-KLH conjugate were shown to be specific for their respective immunizing peptides by ELISA. The induction of high

titers of peptide-specific IgG antibodies by free peptide clearly indicates that the peptide comprises both a functional T-helper determinant and a B-cell epitope(s). In addition, anti-HIBP1-4, anti-HIBP1-5, anti-HIBP1-7, anti-HIBP1-9, anti-HIBP1-10, anti-HIBP1-11 and anti-HIBP1-14 antisera recognised P1 in all assays used, which indicates that these regions are antigenic and free to interact with antibodies. Since these peptides were shown to contain potent T-helper determinant and peptide-KLH conjugates induced strong IgG antibody responses in rabbits, it is obvious that they can act as antigens in a vaccine preparation.

It was of interest to determine whether Hib P1 peptide-specific antisera would cross-react with native P1 from non-typeable strains of H. influenzae. Rabbit antisera raised against the synthetic peptides HIBP1-1, HIBP1-3, HIBP1-5, HIBP1-6, HIBP1-7, HIBP1-9, HIBP1-12 and HIBP1-13 recognized the P1 protein from both typeable and non-typeable isolates. These results suggest that the peptides corresponding to residues 1 to 29, 39 to 64, 103 to 137, 189 to 218, 226 to 253, 248 to 283, 307 to 331, and 400 to 437 of the mature P1 protein, contain epitopes highly conserved among typeable and non-typeable strains of H. influenzae.

Rabbit antisera raised against P2 peptide-KLH conjugates were assayed for reactivity against native P2 in P2-specific ELISAs and by immunoblot analysis. Although all peptide-specific antisera, except antisera raised against HIBP2-26-KLH and OMP2-13-KLH conjugates, recognized P2 in the immunoblots, only Porin-1, OMP2-5, -7, -8, -10, -12, and CHIBP2 peptide-KLH conjugates were found to elicit antibodies that cross-reacted with native P2 in the P2-specific ELISA (Table 9 below). All unconjugated peptides except for Porin-1 and HIBP2-26 emulsified in complete Freund's adjuvant induced very strong peptide-specific antibody responses against P2 in

immunoblots (Table 9 below). In addition, antisera raised against unconjugated peptides OMP2-4, -8, -10, -11, -12, and -13 reacted strongly with purified P2 in the P2-specific ELISA. These data indicate that these peptides contain potent functional T-helper cell epitopes and immungenic B-cell epitopes. Furthermore, P2 purified from three different non-typeable isolates SB30, SB32 and SB33 were used as target antigens in immunoblots. Rabbit anti-Porin-1, OMP2-5, -8, -10, -11, -12 and -13 antisera reacted strongly with P2 from all three non-typeable isolates. These results suggest that the peptides corresponding to residues 1-19, 125-150, 183-219, 241-265, 263-289, 285-306 and 302-319 contain epitopes conserved among typeable and non-typeable strains of H. influenzae.

Rabbit antisera raised against P6 peptides were assayed for reactivity against P6 in the P6-specific ELISA and by immunoblot analysis. All peptide-specific antisera, except those raised against P6-4, recognized native P6 in the P6-ELISA, and were found to cross-react with both typeable and non-typeable P6 in immunoblots (Table 10 below). These data indicate that P6 peptides contain potent functional T-helper cell epitopes and immunogenic B-cell epitopes. Furthermore, these results confirm that the P6 protein is highly conserved among typeable and non-typeable strains of H. influenzae. Therefore, these conserved epitopes of P1, P2 and P6 can be used either individually or in combination to prepare a cross-reactive (typeable and non-typeable strains of Hi) synthetic vaccine. Peptides described above can be further either polymerized, or modified with lipids as lipopeptides or linked to synthetic PRP as synthetic glycopeptide or lipoglycopeptide conjugates to produce alternate vaccines. These vaccines can be used to immunize against Hi infection when administered to mammals, for example, by the intramuscular or parenteral

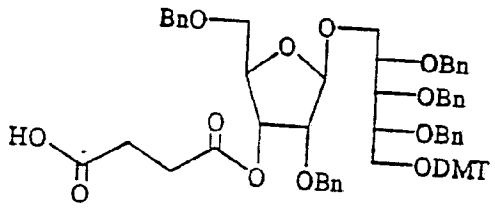
route, or when delivered to the mucosal surface using microparticles, capsules, liposomes and targeting molecules such as toxins and antibodies.

Further experiments were performed to determine whether synthetic chimeric peptides comprising identified immunodominant T-and B-cell epitopes from either P1 or P2 or P6 linked in tandem could elicit strong protective antibody responses against Hi infection. The peptides containing the amino acid sequences VKTIGDKRTLTLNTCARTRTTETGKGVKTEKEKSVGVGLRVYF, VKTIGDKNTLTLNTFGDGFYAQGYLETRFVTKASENGSNFGDC, VKTIGDKNTLTLNTCGANYLLAQKREGAKGENKRPNDKAGEV, VKTIGDKRTLTLNTDIVAKIAYGRTNYKYNESDEHKQQLNGC, VKTIGDKRTLTLNTYAKTKNYKIKHEKRYFVSPGFQYELC, GYLETRFVTKASENGSDFKEVKTIGDKRTLTLNTTANYTSQAHANLYGLNLNYSF, AKGENKRPNDKAGEVFKEVKTIGDKRTLTLNTTANYTSQAHANLYGLNLNYSF, and ARTRTTETGKGVKTEKFKEVKTIGDKRTLTLNTTANYTSQAHANLYGLNLNYSF (SEQ ID NOS: 42 to 49 respectively) were synthesized, purified and used to immunized rabbits in the presence of either CFA or alum. The results are summarized in Table 11 below. All anti-peptide antisera strongly reacted with the respective immunizing peptides, but not all chimeric peptides elicited antibodies against the native OMPs. The best immunogens were peptides 1P13-2P8 and 2P6-1P13, which elicited antibodies recognizing both the native P1 and P2 proteins when adminstered in the presence of alum. Since these peptides contain epitopes conserved among Hi strains, they can be used as additional antigen or modified as lipopeptides, or linked to synthetic PRP oligomers as vaccines. These vaccines can be used to immunize against Hi infection when administered to mammals, for example, by the intramuscular or parenteral route, or when delivered to the surface mucosal surface using microparticles, capsules, liposomes and targeting molecules such as toxins and antibodies.

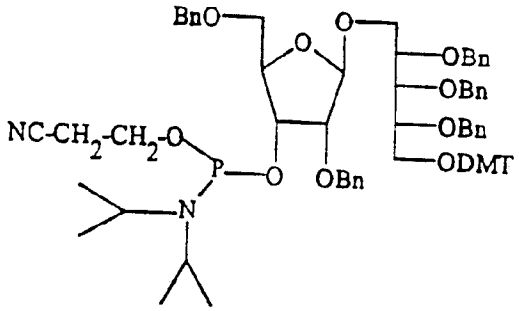
Synthesis of PRP oligosaccharide fragments using PEG

The synthetic PRP is prepared by a combination of solid/liquid-phase synthesis and the highly efficient phosphoramidite method, as outlined in Figures 13 and 14. It is a novel process that utilizes polyethylene glycol monomethyl ether (PEG) as solid support. The solid-phase support contains high number of chemically reactive functional groups ranging from about 200 to 500 μmol/g of support, as compared to the about 30 to 35 μmoles of reactive groups per g of conventional supports, such as controlled pore glass. The synthesis uses only stoichiometric amounts of synthetic PRP repeating unit in each coupling cycle, as compared to a 5 to 10 fold molar excess in the conventional solid-phase synthesis. Furthermore, PEG is soluble in the reaction solvents so that the coupling efficiency is about 95 to 98% for each cycle. At the end of the cycle, PEG-bound synthetic PRP is precipitated with ether to remove any by-products. For the synthetic PRP hexamer, the final yield was about 70%. Thus, the present synthesis process is very fast, cost-effective and simple to scale-up for commercial applications, in contrast to solution-phase synthesis which is labourious, expensive and time-consuming.

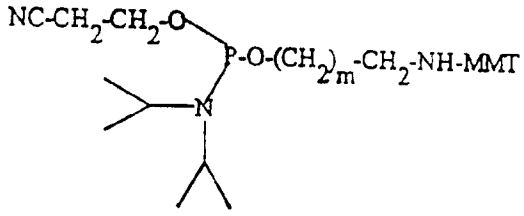
The following paragraphs describe the synthesis process in greater details. The PRP repeating unit for oligomer initiation is a compound represented by the formula:



where Bn and DMT are benzyl and dimethoxytrityl groups, respectively. This repeating unit is coupled to PEG as described in Example 10 below, detritylated with trichloroacetic acid (TCA), and then coupled with another PRP repeating unit for chain elongation, represented by the formula:

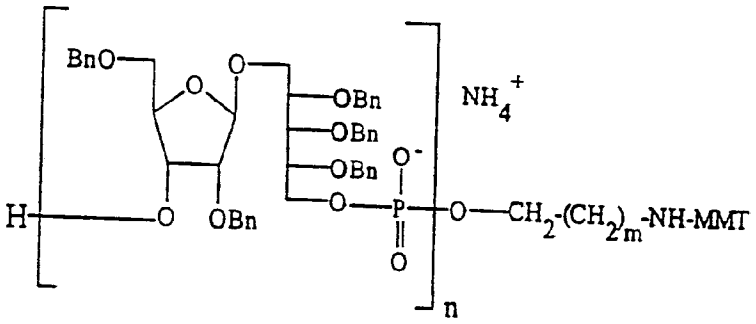


The resulting compound is then detritylated with TCA. In each cycle, the chain elongation is accomplished by coupling the detritylated chain in the presence of a catalyst, preferably tetrazole. After each coupling step the oxidation of phosphorous is accomplished using an oxidizing agent, preferably t-butyl hydroperoxide. The synthesis cycle (Detritylation, coupling, and oxidation steps) is repeated until an oligomer of the desired length is obtained. The PRP oligomer is terminated by reacting with a chain terminator represented by the following formula:



where m is an integer, preferably from 4 to 6, and MMT is monomethoxytrityl. After chain termination the resulting PEG-supported oligomer, which forms one aspect of this invention, is then cleaved from the solid support,

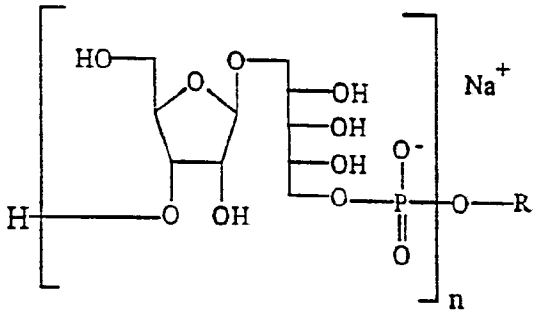
preferably through cleavage by ammonolysis. The recovered material is represented by the formula:



where n is an integer, preferably from 3 to 20, and m is an integer, preferably from 4 to 6, Bn is benzyl, and MMT is monomethoxytrityl. The compound is associated with a counter ion. Preferably, the ion is ammonium, as illustrated, or substituted ammonium.

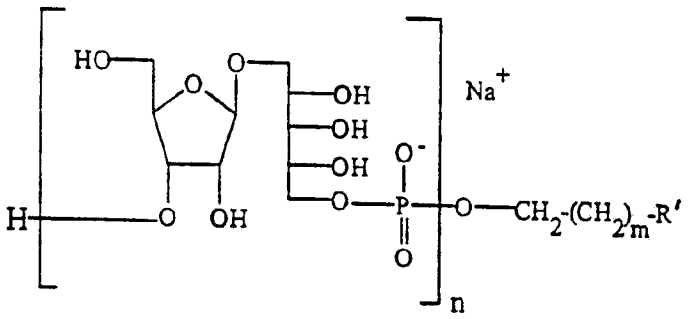
The side-chain protecting groups are removed by hydrogenation with palladium on charcoal in the presence of water/acetic acid/t-butyl alcohol as described in Example 10 below. The resulting oligomer may be purified by standard techniques, preferably by combination of gel and anion exchange chromatography.

As described above, coupling the compound X6 (Fig. 14) at the last step before chain-termination, it is very easy to convert the synthetic PRP oligomer to comprise a chemically reactive functional group represented by the following formula:



where n is an integer, preferably from 3 to 20, and R is a linker fragment defined by $-CH_2-(CH_2)_m-X$, wherein m is an integer, preferably from 3 to 5, inclusive, and X is a chemically reactive functional group, such as $-CH_2NH_2$, $-CH_2SH$, or an amino-reactive group such as an halogen, methanesulfonyl, triflouromethanesulfonyl or toluenesulfonyl, and the like, or a photoactivatable group, such as phenyl azide, nitrophenyl, benzylphenyl, and the like.

The compound containing the functional group may be formed in a conjugate in the most preferred embodiment of the invention, the conjugate being represented by the following formula:



where n is an integer, preferably from 3 to 20, and m is an integer, preferably from 3 to 5, and R' is $-(CH_2-$carrier), wherein Y is a linker molecule which may be m-maleimidibenzoyl-N-hydroxysuccinimide and the carrier is a Hi peptide or MAP system thereof. The conjugate will be associated with a counter ion. Preferably, the ion is Na^+, as illustrated.

It is obvious that there are numerous ways to prepare synthetic PRP. The technology that includes those known in the art, for example, the European Patent Office Publications 0 320 942 (ref. 28) and 0 276 516 (ref. 27), as well as those ones that could be used in conjunction with the present invention, are well within the scope of the invention.

Immunochemical Characterization of Synthetic PRP Oligosaccharide Conjugated to Peptides Containing T-helper cell Epitope(s)

Peptides which may be utilized according to the invention include any peptide which is safe when administered to young mammals and may serve as an immunologically effective T-cell epitope, for example, P24E, a human T-cell epitope from the HIV-1 gag protein p24 (Fig. 1). In particular embodiments, peptides from outer membrane proteins of Hib were used and the conjugation technology was fully described in Examples 11 and 13 below. To determine the minimum number of repeating units required to generate anti-PRP IgG antibody response, synthetic PRP oligomers (dimer and trimer) were coupled to tetanus toxoid and the glycoconjugates injected into rabbits in the presence of alum. The results presented in Figure 15, indicate that, to be immunogenic the synthetic PRP oligomer requires at least three repeating units.

According to the invention, the fully synthetic PRP-peptide conjugate vaccine candidates were prepared by coupling synthetic PRP oligomers to well characterized synthetic T-cell epitopes of Hib OMPs through a cysteine residue added either at the N-terminal or the C-terminal end of the peptides, for example, peptide HIBP1-4 (residues 165-193 of the P1 protein) which had been identified to comprise a Hib strain-specific protective B-cell epitope and at least one functional T-helper cell epitope.

To prepare an effective synthetic PRP-peptide conjugate vaccine, several factors which may affect the immunogenicity of the carbohydrate antigen need to be carefully examined. These factors are (i) the chain length of the oligosaccharide; (ii) the site of conjugation of sugar moieties with respect to the T-cell epitope; (iii) the density of carbohydrate antigen on the

peptide; (iv) the conjugation methodologies which influences the stability of the glyconjugate; (v) the requirement of linkers or spacers between the carbohydrate moiety and the carrier peptide for opimal antigen presentation and processing. To this end, a pair of peptides, HIBP1-4 and CHIBP1-4 (Fig. 1) which differ only by an additional cysteine residue added either at the C-terminal end (HIBP1-4 - SEQ ID NO: 51) and the N-terminal end (CHIBP1-4 - SEQ ID NO: 52), respectively, were synthesized, purified, and used as T-cell epitope carriers to examine the effect of the orientation of sugar moiety relative to the T-cell epitope on the construct immunogenicity. A synthetic PRP trimer was used as carbohydrate antigen. The two PRP-peptide conjugates (PRP-CHIBP1-4 and HIBP1-4-PRP) were prepared and injected into rabbits in the presence of alum. After 3 immunizations, the rabbit antisera were assayed for anti-PRP and anti-peptide IgG antibody titers. Both conjugates elicited strong anti-peptide and anti-P1 antibody responses, but only the synthetic HIBP1-4-PRP elicited an anti-PRP IgG antibody response. These results suggest that the orientations of the sugar moiety relative to the T-cell epitope may significantly influence the host immune response to the carbohydrate antigen.

To determine whether all peptides containing functional T-cell epitope(s) could efficiently present synthetic PRP oligomers to the immune system, two more peptides (COMP2-8 - SEQ ID NO: 53 and P24EC - SEQ ID NO: 56) known to contain functional T-cell epitope(s), were conjugated to the synthetic PRP trimer. The glycopeptide conjugates were absorbed to alum and used to immunize rabbits. The results are summarized in Table 12 below. Both glycopeptide conjugates (COMP2-8-PRP and P24EC-PRP) elicited anti-PRP IgG antibody responses.

To determine the effect of carbohydrate density on the immunogenicity of synthetic glycopeptide conjugate vaccines, the synthetic PRP trimer was conjugated to a multiple antigen peptide system (MAPs) containing eight branched OMP2-8 peptides(residues 193-219 of the P2 protein) (Fig. 1 - SEQ ID NO: 54). Although nine cysteine residues were available for conjugation purposes, only five PRP trimer molecules were found to be coupled to one MAP molecule. Nevertheless, after three injections of 50 μg of the synthetic glycopeptide conjugate in the presence of alum, both rabbits mounted a strong anti-PRP IgG antibody response. The anti-PRP IgG antibody titer was about four-fold higher than those obtained with the linear peptide-PRP conjugate (Table 12 below). Furthermore, the anti-peptide and anti-P2 antibody reponses were 1 to 2 orders of magnitude higher than those obtained with the linear peptide-PRP conjugate. Further analysis of the results shown in Figure 16 revealed that Hib MAPs conjugated to synthetic PRP oligomers are good vaccine candidates which can elicit high titers of anti-PRP IgG antibodies comparable to those obtained with native PRP coupled to either diphtheria toxoid or P1 or P2 proteins.

To determine whether the length of the carbohydrate repeating units affected the immunogenicity of the carbohydrate antigen in the glycoconjugate, the synthetic PRP dimer, trimer, pentamer, hexamer and native PRP (molecular weight 30 kDa) were coupled either to linear peptide HIBP1-4 and OMP2-8 MAP, respectively. Surprisingly, both peptides conjugated to native PRP failed to elicit anti-PRP IgG antibody responses. In contrast, both the PRP pentamer and hexamer conjugated to the linear peptide HIBP1-4 elicited a strong and consistent anti-PRP IgG antibody response (Fig. 17). The OMP2-8 MAP conjugated to the synthetic PRP hexamer was also highly immunogenic. The synthetic PRP dimer was not

immunogenic and was consistent with previous results described above.

Utility of Synthetic glycopeptide Conjugation Technology

In preferred embodiments of the present invention, the glycoconjugate technology can be generally utilized to prepare conjugate vaccines against pathogenic encapsulated bacteria. Thus, the glycoconjugate technology of the present inventions may be applied to vaccinations to confer protection against infection with any bacteria expressing potential protective polysaccharidic antigens, including Haemophilus influenzae, Streptococcus pneumoniae, Escherichia coli, Neisseria meningitidis, Salmonella typhi, Streptococcus mutans, Cryptococcus neoformans, Klebsiella, Staphylococcus aureus and Pseudomonas aerogenosa.

In particular embodiments, the synthetic glycoconjugate technology may be used to produce vaccines eliciting antibodies against proteins or oligosaccharide. Such vaccines may be used, for example, to induce immunity toward tumor cells, or to produce anti-tumor antibodies that can be conjugated to chemotherapeutic or bioactive agents.

It is understood that the application of the methology of the present invention is within the capabilities of those having ordinary skills in the art. Examples of the products of the present invention and processes for their preparation and use appear in the following Examples.

It is also understood that within the scope of the invention are any variants or functionally equivalent variants of the above peptides. The terms "variant" or "functionally equivalent variant" as used above, mean that if the peptide is modified by addition, deletion or derivatization of one or more of the amino acid residues, in any respect, and yet acts in a manner similar to that of P1, P2 and P6 peptides for any Haemophilus influenzae

isolates, then it falls within the scope of the invention.

Given the amino acid sequence of these peptides (Tables 1 to 3 and 11) and any similar peptide, these are easily synthesized employing commercially available peptide synthesizers, such as the Applied Biosystems Model 430A, or may be produced by recombinant DNA technology.

The above disclosure generally describes the present invention. A more complete understanding can be obtained by reference to the following specific Examples. These Examples are described solely for purposes of illustration and are not intended to limit the scope of the invention. Changes in form and substitution of equivalents are contemplated as circumstances may suggest or render expedient. Although specific terms have been employed herein, such terms are intended in a descriptive sense and not for purposes of limitations. Immunological methods may not be explicitly described in this disclosure but are well within the scope of those skilled in the art.

EXAMPLES

Example 1

Preparation of 2,3,4-Tri-O-benzyl-1-O-[2,5,-di-O-benzyl-β-D-ribofuranosyl]-5-O-(4,4'-dimethoxytrityl)-D-ribitol (compound 14, Fig. 14).

At room temperature, a 4,4'-dimethoxytrityl chloride (6.2 g) was added to a 200 mL of dichloromethane solution of containing 10.2 g of 2,5-di-O-benzyl-β-D-ribofuranosyl 2,3,4-tri-O-benzyl-D-ribitol (compound 13, in Fig. 14) prepared from D-ribose via 12 intermediate products as previously described (refs. 33 to 36), pyridine (3.4 mL) and 4-dimethylaminopyridine (860 mg). After stirring for 18-24 h, the reaction mixture was poured into a saturated solution of sodium bicarbonate. The aqueous layer was extracted with dichloromethane, dried and the solvents

were evaporated. The product was purified using silica gel chromatography, and its structure was confirmed by NMR.

Example 2

Preparation of 2,3,4-Tri-O-benzyl-1-O-[2,5-di-O-benzyl-3-O-succinyl-β-D-ribofuranosyl]-5-O-(4,4'-dimethoxytrityl)-D-ribitol (compound 16, Fig. 13)

To a solution of 1.34 g of the product from Example 1 in dry pyridine (4.5 mL) were added succinic anhydride (390 mg) and 4-dimethylaminopyridine (240 mg). The reaction mixture was stirred in a water bath at 50 to 80°C for 3 to 10 h. After the addition of water (2.0 mL) the reaction mixture was concentrated by rotory evaporation. Chromatography of the mixture on a column of silica gel using dichloromethane:methanol:triethylamine in a ratio of 95:5:2.5 (V:V:V) provided the product as a triethylammonium salt whose structure was confirmed by NMR.

Example 3

Preparation of ribosylribitol phosphoramidite

To a solution of Compound 16 (1.2 g in 5 mL of dry dioxane), N,N-diisopropylethylamine (1.4 mL) and 2-cyanoethyl N,N-diisopropylchlorophosphoramidite (640 μL) were added. After stirring for 1-3 h, additional amounts of N,N-diisopropylethylamine (430 μL) and 2-cyanoethyl N,N-diisopropylchlorophosphoramidite (250 μL) were added. The reaction mixture was diluted 3-fold with dichloromethane and extracted with an equal volume of 1M triethylammonium bicarbonate solution, brine solution and dried with anhydrous sodium sulphate. The product was purified on silica gel, and its structure was confirmed by NMR.

Example 4

Preparation of 1-t-Butyldimethylsilyloxy-6-cyano-hexane (compound X2, Fig. 14)

Sodium cyanide (1.2 g) dissolved in dimethylsulphoxide was heated at 90°C for 30 min. Solid 1-t-butyldimethylsilyloxy-6-bromohexane (5.8 g, compound X1) prepared according to the method previously described (ref. 37), then was added into the sodium cyanide solution. After heating at 120-130°C for 20-180 min, the reaction mixture was poured into ice-cold water and the aqueous layer was extracted with ether, washed with brine, dried and concentrated. The product was distilled at 0.5 Torr and 107°C to give a colourless oil. High resolution mass spectrometer for C12 H24 O N Si: calculated 226.1627, found 226.1624.

Example 5

Preparation of 7-Amino-1-t-butyldimethylsilyloxy-heptane (compound X3, Fig 14)

To a solution of lithium aluminium hydride (600 mg, Aldrich) in ether (50 mL) was added dropwise the product (3.8 g) from Example 4 in ether (50 mL). After 1-3 h, the mixture was poured into water and stirred for 30 min. The insoluble aluminium hydroxide was filtered through a celite pad, and the aqueous layer was extracted with ether three times. The ether extracts were washed with brine solution, dried and concentrated. The crude product was distilled at 0.25 Torr and 82°C. High resolution mass spectrum for C13 H31 O N Si: calculated 245.2175, found 245.2159.

Example 6

Preparation of (N-Monomethoxytrityl)-7-amino-1-t-butyldimethylsilyloxy-heptane (compound X4, Fig. 14)

Monomethoxytrityl chloride (3.7 g, Aldrich) was added to a solution of the product (2.3 g) from Example 5 in dichloromethane (40 mL). After stirring at room temperature for 10 to 24 h, the solution was poured into a solution of saturated sodium bicarbonate. The aqueous layer was extracted with dichloromethane. The dichloromethane extracts were washed with brine solution

and dried. The solvent was evaporated and the product was purified on silica gel chromatography. The purified compound X4 was analysed by high resolution mass spectrometer. C33 H47 O2 N Si: calculated 517.3376, found 517.3355.

Example 7

Synthesis of N-Monomethoxytrityl-7-aminoheptanol (compound X5, Fig 14)

A 1M Solution of tetrabutylammonium fluoride (25.8 mL) was slowly added to a solution of the compound X4 (4.3 g) in tetrahydrofuran (46 mL). After stirring at room temperature for 4 to 18 h, the solution was poured into 100 mL of water and stirred for another 30 min. The organic phase was extracted with brine solution and dried. The crude product was then purified on silica gel. The purified product was analysed by high resolution mass spectrometry. C27 H33 O2 N: calculated 403.2511, found 403.2514.

Example 8

Preparation of N-Monomethoxytrityl-7-aminoheptyl (2-cyanoethyl)-N,N-diethylphosphoramidite (compound X6, Fig. 14)

To a solution of compound X5 (240 mg) in dioxane (10 mL) was added diisopropylethylamine (840 µL) and 2-cyanoethyl -N,N-diisopropylchlorophosphoramidite (270 µL). After stirring for 1 h, the reaction mixture was diluted with dichloromethane and washed with 1M solution of triethylammonium bicarbonate and finally with brine solution. After drying and concentrating, the residue was purified by silica gel chromatography. The product was analysed by high resolution mass spectrometry. C36 H50 N3 O3 P:calculated 603.3620, found 603.3620. The structure of the product was also comfirmed by NMR analysis.

Example 9

Preparation of succinyl ribosylribitol-PEG (Fig. 14)

To a solution of compound 16 (1.8 g) in dichoromethane (18 mL), N-hydroxybenzotriazole (295 mg) and dicyclohexylcarbodiimide (450 mg) were added. The reaction mixture was stirred at room temperature. After 2-8 h, dicyclohexylurea was removed by filtration. The filtrate, N-methylimidazole (522 μL) and diisopropylethylamine (600 μL) were added to polyethylene glycol monomethyl ether, PEG (Average M.wt.5000; 2.1 g, Fluka). The mixture was stirred overnight at room temperature under argon. The functionalized PEG was precipitated with cold ether and filtered. The loading capacity was determined spectrophotometrically according to the method of Gait et al. (ref. 36) and found to be about 200 μmol/g. Free residual hydroxyl groups were capped with a mixture of 20% acetic anhydride/pyridine in dichloromethane for 1 to 3 h at room temperature. The support was then precipitated with cold ether, filtered and washed with cold ether.

Example 10

Preparation of synthetic PRP using soluble-polymeric support (Fig. 13)

One gram of PEG-PRP-DMT (product of Example 9) was evaporated twice with pyridine and dissolved in acetonitrile under argon. The PRP oligosaccharide was elongated in a cycle of four steps, each step being preceded by the precipitation of the functionalized PEG with cold ether to remove by-products, followed by crystallization from dichloromethane/ether. The first step of synthesis involved removal of dimethoxytrityl group using 3% toluene sulfonic acid in chloroform/methanol acid, followed by coupling with the ribosylribitol phosphoramidite product from Example 3 in the presence of tetrazole (180 min). The coupling efficiency was determined to be 95%. Oxidation (step 3)

was performed using 70% t-butyl hydroperoxide solution (120 min), and finally capping (step 4) using 20% acetic anhydride/pyridine in dichloromethane (60 min). Two cycles of synthesis were performed, followed by coupling the spacer phosphoramidite product from Example 8. The resin was then heated with aqueous concentrated ammonia tetrahydrofuran for 17 to 24 h at 50 to 100°C. The mixture was filtered to remove PEG, washed and the solvents were evaporated. Hydrogenolysis of the product in the presence of 10% Pd/charcoal in t-butyl alcohol/water/acetic acid (4:3:1) using a medium pressure hydrogenation apparatus at 40 psi provided a homogeneous product after filtration. The product was lyophilized, and then purified by a combination of gel filtration over a column of Sephadex G-25 in 0.01M triethylammonium bicarbonate pH 7, followed by ion exchange chromatography on Sephadex C-25 using water. Lyophilization of the appropriate fractions provided a solid product whose structure was analysed by NMR. A spectrum of ribosylribitol phosphate trimer was obtained and found to be similar to that reported by Hoogerhout et al. (J. Carbohydr. Chem. 7, 399, 1988).

Example 11

Modification of synthetic $(PRP)_3$ with m-Maleimidobenzoyl-N-hydroxysuccinimide

A solution of m-Maleimidobenzoyl-N-hydroxysuccinimide (20 mg ; 63.6 µmol) in tetrahydrofuran (1 mL) was added to a solution of synthetic $(PRP)_3$ (5.2 mg ; 4.3 µmol) in 0.1 M phosphate buffer solution (1 mL), pH 7.5. After stirring the solution for 30 min at room temperature under argon, the reaction mixture was extracted with ether (4 X 5 mL), and the resulting aqueous layer was applied to a Sephadex G-25 (Pharmacia) column (2 x 30 cm) equilibrated with 0.1 M triethylammonium acetate buffer, pH 7.2, and eluted with the same buffer. Elution was monitored

spectrophotometrically at 254 nm. The first eluted peak was pooled and lypholized. The amount of maleimide groups incorporated into $(PRP)_3$ was determined using a modified Ellman's method (ref. 39), and found to be 90% incorporation.

Example 12

Peptide synthesis

Peptides from OMP P1, P2 and P6 (Tables 1 to 3) were synthesized using an ABI 430A peptide synthesizer and optimized t-Boc chemistry as described by the manufacturer, then cleaved from the resin by hydrofluoric acid (HF). The peptides were purified by reverse-phase high performance liquid chromatography (RP-HPLC) on a Vydac C4 semi-preparative column (1 x 30 cm) using a 15 to 55% acetonitrile gradient in 0.1% trifluoryl acetic acid (TFA) developed over 40 minutes at a flow rate of 2 mL/min. All synthetic peptides (Tables 1-3) used in biochemical and immunological studies were >95% pure as judged by analytical HPLC. Amino acid composition analyses performed on a Waters Pico-Tag system were in good agreement with the theoretical compositions. The synthetic MAP $(OMP2-8)_8$ was manually prepared using t-Boc solid-phase peptide synthesis chemistry according to the method previously described by Tam et al. (ref. 40). Cysteine residues were added at both N- and C-terminal ends of the peptide for PRP-conjugation purposes. The MAP peptide was purified by RP-HPLC as previously described.

Example 13

Preparation of fully synthetic peptide-$(PRP)_3$ conjugates

One to two milligrams of individual synthetic peptides $(OMP2-8)_8$ and HIBP1-4 were dissolved in 0.5 mL of well-degassed water, and 0.8 mL of MBS-$(PRP)_3$ (1.6 mg) in well-degassed water was added. The resulting mixture was stirred at room temperature under argon overnight. The insoluble precipitate was removed by centrifugation,

and the supernatant subjected to gel filtration chromatography on a column of G-50 Sephadex (2 x 30 cm) equilibrated in 0.1 M triethylammonium acetate buffer, pH 7.2, to remove excess MBS-$(PRP)_3$. The synthetic peptide-$(PRP)_3$ conjugates were collected and analysed by reversed phase HPLC, Orcinol test and amino acid analysis. The molar ratio of peptide to PRP was about 1:1 and 1:5 for HIBP1-4 and MAP peptide conjugates, respectively. The synthetic peptide-PRP conjugates were then absorbed onto alum for immunogenicity studies.

Example 14

Preparation of native PRP-BSA conjugate

A 0.5 mL of periodate-oxidized PRP (25mg in 1 mL of 0.1 M sodium phosphate buffer, pH 6.0), prepared from native PRP treated with aqueous periodic acid (4), was added to bovine serum albumin (BSA) (1.32 mg ; 0.02 µmol) in 0.5 mL of 0.2 M sodium phosphate buffer, pH 8.0, followed by the addition of sodium cyanoborohydride (14 µg ; 0.22 µmol ; 10 eqv. to BSA). After incubation at 37°C for 5 days, the reaction mixture was dialysed against 0.1 M phosphate buffer (4 X 1 L), pH 7.5, and the resulting solution was applied onto an analytical Superose 12 column (15 x 300 mm, Pharmacia) equilibrated with 0.2 M sodium phosphate buffer, pH 7.2, and eluted with the same buffer. Fractions were monitored for absorbance at 230 nm. The major peak was pooled and concentrated in a Centriprep 30 (Pierce) to 2.2 ml. The amount of protein was determined using the Bio Rad protein assay, and was found to be 300 µg/ml. Derivatization with PRP was confirmed by the Orcinol test.

Example 15

Production of anti-peptide and anti-OMP antisera

Rabbits, mice (Balb/C) and guinea pigs were immunized itramuscularly (im) with native P1 or P2 or P6 or individual peptides (5 to 100 µg) emulsified in

complete Freund's adjuvant, and followed by two booster doses (half amount of the same immunogen in incomplete Freund's adjuvant) at 2 week intervals. Antisera were collected and stored as described above.

Exampel 16

Production of anti-PRP antisera

Rabbits were immunized intramuscularly with individual PRP-carrier conjugates (5-50 μg PRP equivalent) mixed with 3 mg $AlPO_4$ per mL, followed by two booster doses (half amount of the same immunogen) at 2 week intervals. Antisera were collected every 2 weeks after the first injection, heat-inactivated at 56°C for 30 min and stored at -20°C.

Example 17

P1-, P2-, P6- and peptide-specific ELISAs

Microtiter plate wells (Nunc-Immunoplate, Nunc, Denmark) were coated with 200 ng of purified OMPs or 500 ng of individual peptides in 50 μL of coating buffer (15 mM Na_2CO_3, 35 mM $NaHCO_3$, pH 9.6) for 16 hr at room temperature. The plates were then blocked with 0.1% (w/v) BSA in phosphate buffer saline (PBS) for 30 min at room temperature. Serially diluted antisera were added to the wells and incubated for 1 hr at room temperature. After removal of the antisera, the plates were washed five times with PBS containing 0.1% (w/v) Tween-20 and 0.1% (w/v) BSA. $F(ab')_2$ from goat anti-rabbit, guinea pig, mouse, or human IgG antibodies conjugated to horseradish peroxidase (Jackson ImmunoResearch Labs Inc., PA) were diluted (1/8,000) with washing buffer, and added onto the microtiter plates. After 1 hr incubation at room temperature, the plates were washed five times with the washing buffer. The plates were then developed using tetramethylbenzidine (TMB) in H_2O_2 (ADI, Toronto) as substrate. The reaction was stopped with 1N H_2SO_4 and the optical density was measured at 450 nm using a Titretek Multiskan II (Flow Labs., Virginia). Two irrelevant

pertussis toxin peptides NAD-S1 (19 residues and S3(123-154) (32 residues) were included as negative controls in the peptide-specific ELISAs. Assays were performed in triplicates, and the reactive titre of an antiserum was defined as the dilution consistently a showing two-fold increase in O.D. value over that obtained with the pre-immune serum.

Example 18

Anti-PRP antibody measurement

Microtiter plate wells (Nunc-Immunoplate, Nunc, Denmark) were coated with 200 ng of purified PRP-BSA in 200 μL of coating buffer (15 mM Na_2CO_3, 35 mM $NaHCO_3$, pH 9.6) for 16 hr at room temperature. The plates were then blocked with 0.1% (w/v) BSA in phosphate buffer saline (PBS) for 30 min at room temperature. Serially diluted antisera raised against PRP-carrier conjugates were added to the wells and incubated for 1 hr at room temperature. After removal of the antisera, the plates were washed five times with PBS containing 0.1% (w/v) Tween-20 and 0.1% (w/v) BSA. $F(ab')_2$ from goat anti-rabbit IgG antibodies conjugated to horseradish peroxidase (Jackson ImmunoResearch Labs Inc., PA) were diluted (1/8,000) with washing buffer, and added onto the microtiter plates. After 1 hr incubation at room temperature, the plates were washed five times with the washing buffer. The plates were then developed using the substrate tetramethylbenzidine (TMB) in H_2O_2 (ADI, Toronto), the reaction was stopped with 1N H_2SO_4 and the optical density was measured at 450 nm using a Titretek Multiskan II (Flow Labs., Virginia). A standard anti-PRP antiserum was included as positive control. Assays were performed in triplicates, and the reactive titre of an antiserum was defined as the dilution consistently showing a two-fold increase in O.D. value over that obtained with the pre-immune sera.

Example 19

Proliferation Assay for Synthetic T-cell Epitopes

T-cell epitope mapping was performed by priming Balb/c, C57Bl/6 and A/J mice with 5 μg of individual OMPs (P1, or P2 or P6). Three weeks later, the spleens were removed and the splenocytes cultured in RPMI 1640 (Flow Lab) supplemented with 10% heat-inactivated fetal calf serum (Gibco), 2 mM L-glutamine (Flow Lab), 100 U/mL penicillin (Flow Lab), 100 μg/mL streptomycin (Flow Lab), 10 unit/mL rIL-2 and 50 μM 2-mercaptoethanol (sigma) for 5 to 7 days. Proliferative responses of the primed splenocytes to the panel of OMP peptides were determined in a standard in vitro assay (ref. 41). Briefly, 10^6 splenocytes were co-cultured in a 96-well microtiter plate with 5 x 10^5 irradiated (1700 Rad) fresh syngeneic spleen cells used as source of antigen presenting cells (APC) in the presence of increasing molar concentrations (0.03 to 3 μM of peptide dissolved in the culture medium without IL-2). Cultures were kept for 40 hr in a humidified 5% CO_2/air incubator maintained at 37°C. During the final 16 hr of culture, 0.5 μCi of [^{3}H]-Tdr (5 Ci/mmol, NEN) was added to each wells. The cells were then harvested onto glass fibre filters, and the incorporation of ^{3}H-thymidine into cellular DNA was measured in a scintillation β-counter (Beckman). Results are expressed as the mean of triplicate determinations performed for each peptide concentration. The standard deviation was always <15%. Proliferative responses were considered as positive when ^{3}H-thymidine incorporation was three-fold above that obtained with either irrelevant peptides or the culture medium.

Example 20

Immunoblot Analysis

The immunospecificity of antisera raised against peptides and PRP-carrier conjugates were determined by immunoblot analysis as previously described (ref. 42).

SUMMARY OF DISCLOSURE

In summary of this disclosure, the present invention provides immunogenic synthetic peptides which are useful alone or in PRP-conjugates in vaccines against Hi infection. Modifications are possible within the scope of the invention.

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TABLE 1

OVERLAPPING PEPTIDES of Hib OMP P1

PEPTIDES	SEQUENCES	SEQ ID NO:
HIBP1-1 (1-29)	AAFQLAEVSTSGLGRAYAGEAAIADNASV(C)	- SEQ ID NO: 1
HIBP1-2 (60-88)	GDVTSYAQIITNQIGMKAIKDGSASQRNV(C)	- SEQ ID NO: 2
HIBP1-3 (103-137)	(C)VNDKFALGAGMNVNFGLKSEYDDSYDAGVFGGKTD	- SEQ ID NO: 3
HIBP1-4 (165-193)	YAKAQVERNAGLIADSVKDNQITSALSTQ(C)	- SEQ ID NO: 4
HIBP1-5 (189-218)	ALSTQQEFRDLKKYLPSKDKSVVSLQDRA(C)	- SEQ ID NO: 5
HIBP1-6 (226-253)	(C)AGVMYQFNEANRIGLAYHSKVDIDFADR	- SEQ ID NO: 6
HIBP1-7 (248-283)	IDFADRTATSLEANVIKEGKKGNLTFTLPDYLELSG(C)	- SEQ ID NO: 7
HIBP1-8 (279-312)	LELSGFHQLTDKLAVHYSYKYTHWSRLTKLHASF(C)	- SEQ ID NO: 8
HIBP1-9 (307-331)	KLHASFEDGKKAFDKELQYSNNSRV(C)	- SEQ ID NO: 9
HIBP1-10	LYEKLTLRAGIAYDQAASRHHRSAAIPDTDRT(C)	- SEQ ID NO: 10

(339-370)		
HIBP1-11 (384-412)	LSVDLGYAYLKGKKVHFKEVKTIGDKRTL(C)	- SEQ ID NO: 11
HIBP1-12 (39-64)	LFKTAQFSTGGVYIDSRINMNGDVTS(C)	- SEQ ID NO: 12
HIBP1-13 (400-437)1H	(C)FKEVKTIGDKRTLTLNTTANYTSQAHANLYGLNLNYSF	- SEQ ID NO: 13
HIBP1-14 (400-437)6U	(C)FKEAQQAAGGFITTTANYTSQAHANLYGLNLNYSF **********	- SEQ ID NO: 14
HIBP1-15 (179-218)	DSVKONDITSALSTQQEFRDLKKYLPSKDKSVVSLQDRA	- SEQ ID NO: 15

* The asterisks point to residues which are different from those found in the P1 protein of the H. influenzae strain 1H (ref. 10)

TABLE 2

Hib OMP P2 OVERLAPPING EPITOPES

PEPTIDES		SEQUENCES	SEQ ID NO:
PORIN 1	1-14	AVVYNNEGTNVELG(C)	- SEQ ID NO: 16
HIBP2-26	8-19	GTNVELGGRLSI	- SEQ ID NO: 17
HIBP2-25	17-32	LSIIAEQSNSTVDNQK	- SEQ ID NO: 18
OMP2-1	28-55	VDNQKQQHGALRNQGSRFHIKATHNFGD(C)	- SEQ ID NO: 19
OMP2-2	53-81	FGDGFYAQGYLETRFVTKASENGSDNFGD(C)	- SEQ ID NO: 20
OMP2-3	79-106	(C)FGDITSKYAYVTLGNKAFGEVKLGRAKT	- SEQ ID NO: 21
OMP2-4	101-129	GRAKTIADGITSAEDKEYGVLNNSDYIP(C)	- SEQ ID NO: 22
OMP2-5	125-150	SDYIPTSGNTVGYTFKGIDGLVLGAN(C)	- SEQ ID NO: 23
OMP2-6	148-174	(C)GANYLLAQKREGAKGENKRPNDKAGEV	- SEQ ID NO: 24
OMP2-7	171-196	AGEVRIGEINNGIQVGAKYDANDIVA(C)	- SEQ ID NO: 25
OMP2-8	193-219	DIVAKIAYGRTNYKYNESDEHKQQLNG(C)	- SEQ ID NO: 26
OMP2-9	219-244	(C)GVLATLGYRFSDLGLLVSLDSGYAKT	- SEQ ID NO: 27
OMP2-10	241-265	YAKTKNYKIKHEKRYFVSPGFQYEL(C)	- SEQ ID NO: 28
OMP2-11	263-289	(C)YELMEDTNVYGNFKYERTSVDQGEKTR	- SEQ ID NO: 29
OMP2-12	285-306	GEKTREQAVLFGVDHKLHKQLL(C)	- SEQ ID NO: 30

OMP2-13	302-319	KQLLTYIEGAYARTRTT(C)	- SEQ ID NO: 31
CHIBP2	314-341	(C)ARTRTTETGKGVKTEKEKSVGVGLRVYF	- SEQ ID NO: 32
OMP2-6U	148-174	(C)GANYLLAQKREGAKMANKLPNNKAGEV ** * *	- SEQ ID NO: 33
OMP2-6L	148-174	(C)GANYLLAQKREGAKGENKQPNDKAGEV *	- SEQ ID NO: 34

* The asterisks point to residues which are different from those found in the P2 protein of the H. influenzae strain 1H (ref. 11).

TABLE 3

OVERLAPPING PEPTIDES OF Hib OMP P6

PEPTIDES	SEQUENCES	SEQ ID NO:
P6-1 (1-22)	CSSSNNDAAGNGAAQTFGGYSV(C)	- SEQ ID NO: 35
P6-2 (19-41)	(C)GYSVADLQQRYNTVYFGFDKYDI	- SEQ ID NO: 36
P6-3 (35-58)	GFDKYDITGEYVQILDAHAAYLNA(C)	- SEQ ID NO: 37
P6-4 (54-77)	(C)AYLNATPAAKVLVEGNTDERGTPE	- SEQ ID NO: 38
P6-5 (73-96)	RGTPEYNIALGQRRADAVKGYLAG(C)	- SEQ ID NO: 39
P6-6 (90-114)	VKGYLAGYLAGKGVDAGKLGTVSYG(C)	- SEQ ID NO: 40
P6-7 (109-134)	(C)GTVSYGEEKPAVLGHDEAAYSKNRRAVLAY	- SEQ ID NO: 41

TABLE 4

Reactivity of antisera raised against OMP P1 determined by P1-specific ELISAs.

SPECIES	IMMUNOGENS	REACTIVE TITER[1]
Human#1	H. influenzae type b[2]	3,200
Human#2	H. influenzae type b	6,400
Human#3	H. influenzae type b	3,200
Guinea pig #390	Native P1	204,800
Guinea pig #392	Native P1	204,800
Mouse (A/J)[3]	Native P1	204,800
Mouse (Balb/C)	Native P1	102,400
Mouse (BL6)	Native P1	102,400
Mouse (C3H)	Native P1	102,400
Mouse (SWR/J)	Native P1	102,400
Rabbit #247*	Native P1	12,800
Rabbit #249	Native P1	6,400
Rabbit #250	Native P1	6,400

[1] Pre-immunization titers were subtracted from post-immunization titers.

[2] Antisera were obtained from convalescent patients.

[3] Two mice per group were used in immunogenicity studies.

* Anti-P1 antisera were shown to be protective in the infant rat model of bacteremia.

TABLE 5

Reactivity of antisera raised against OMP P2 determined by P2-Specific ELISA

SPECIES	IMMUNOGENS	REACTIVE TITER[1]
Human#1	H. influenzae type b[2]	25,600
Human#2	H. influenzae type b	6,400
Human#3	H. influenzae type b	1,600
Guinea pig #52	Native P2	409,000
Guinea pig #RF3430	Native P2	1,638,400
Guinea pig #RF3438*	Native P2	6,553,600
Mouse (A/J)[3]	Native P2	1,600
Mouse (SJL/J)	Native P2	25,600
Mouse (Balb/C)	Native P2	12,800
Mouse (BL6)	Native P2	25,600
Mouse (C3H)	Native P2	12,800
Mouse (SWR/J)	Native P2	6,400
Rabbit #RF3428*	Native P2	819,200
Rabbit #493*	Native P2	6,533,600

[1] Pre-immunization titers were subtracted from post-immunization titers.

[2] Antisera were obtained from convalescent patients.

[3] Two mice per group were used in immunogenicity studies.

* Anti-P2 antisera were shown to be protective in the infant rat model.

TABLE 6

Reactivity of antisera raised against OMP P6 determined by P6-specific ELISA

SPECIES	IMMUNOGENS	REACTIVE TITER[1]
Rat RF6843	Native P6	128,000
Rat RF6880H	Native P6	3,200
Guinea pig #792	Native P6	564,000
Guinea pig #793	Native P6	1,638,400
Guinea pig #794	Native P6	1,253,600
Rabbit #274	Native P6	819,200
Rabbit #276*	Native P6	2,733,600

[1] Pre-immunization titers were subtracted from post-immunization titers.

* Anti-P6 antisera were shown to be protective in the infant rat model.

TABLE 7

Proliferative responses of T-cell lines generated from Balb/c mice immunized with P6 to P6 synthetic peptides

Antigens	Cell Proliferation Index[1]
rP6	**10.5**
Hib P1	1.2
P6-1	1.2
P6-2	**20.5**
P6-3	**10.3**
P6-4	1.3
P6-5	**5.8**
P6-6	0.9
P6-7	**22.4**
P24E	1.4
MEDIUM	1.0

[1] Boldfaced numbers correspond to significant T-cell proliferative responses indicate that immunodominant T-cell epitopes are located within the immunostimulatory peptides.

TABLE 8

PROPERTIES OF RABBIT ANTISERA RAISED AGAINST P1 PEPTIDES

	ANTISERA REACTIVITY AGAINST			
	SPECIFIC-ELISAs		WESTERN BLOT AGAINST P1	
IMMUNOGEN	PEPTIDE	P1	Hib	Non-typeable
HIBP1-1	YES	NO	YES	YES
HIBP1-1-KLH	YES	NO	YES	YES
HIBP1-2	YES	NO	YES	NO
HIBP1-2-KLH	YES	NO	YES	NO
HIBP1-3	YES	NO	YES	YES
HIBP1-3-KLH	YES	NO	YES	YES
HIBP1-4	YES	YES	YES	YES*
HIBP1-4-KLH	YES	NO	YES	NO
HIBP1-5	YES	YES	YES	YES
HIBP1-5-KLH	YES	YES	YES	YES
HIBP1-6	YES	NO	YES	YES
HIBP1-6-KLH	YES	NO	NO	NO
HIBP1-7	YES	NO	YES	YES
HIBP1-7-KLH	YES	YES	YES	YES
HIBP1-8	NO	NO	NO	NO
HIBP1-8-KLH	NO	NO	NO	NO
HIBP1-9	YES	YES	YES	YES
HIBP1-9-KLH	YES	NO	YES	YES
HIBP1-10	YES	NO	YES	NO
HIBP1-10-KLH	YES	YES	YES	YES*
HIBP1-11	YES	YES	YES	YES*
HIBP1-11-KLH	YES	YES	YES	NO
HIBP1-12	YES	NO	YES	YES
HIBP1-12-KLH	YES	NO	YES	YES
HIBP1-13	YES	NO	YES	YES
HIBP1-13-KLH	YES	NO	YES	YES

* Rabbit antisera recognized one or two out of five non-typeable Hi isolates tested.

TABLE 9

Immunological properties of rabbit antisera raised against P2 peptides and peptide-KLH conjugates.

	RECIPROCAL REACTIVE TTTRE AS DETERMINED BY ELISAS[1]		RECOGNITION OF P2 IN IMMUNOBLOTS	
IMMUNOGENS	NATIVE P2	SPECIFIC PEPTIDES	Hib	NON-TYPEABLE
PORIN 1-KLH	3,200	104,800	YES	YES
PORIN 1	<200	<200	NO	NO
HIBP2-25-KLH	<200	25,600	YES	NO
HIBP2-25	<200	102,400	YES	NO
HIBP2-26-KLH	<200	<200	NO	NO
HIBP2-26	<200	<200	NO	NO
OMP2-1-KLH	<200	6,400	YES	NO
OMP2-1	<200	3,200	YES	NO
OMP2-2-KLH	<200	409,600	YES	NO
OMP2-2	<200	204,800	YES	NO
OMP2-3-KLH	<200	3,200	YES	NO
OMP2-3	<200	102,400	YES	NO
OMP2-4-KLH	<200	6,400	YES	NO
OMP2-4	12,800	102,400	YES	NO
OMP2-5-KLH	25,600	204,800	YES	YES
OMP2-5	<200	102,400	YES	YES
OMP2-6-KLH	<200	6,400	YES	NO
OMP2-6	<200	204,800	YES	NO
OMP2-7-KLH	3,200	51,200	YES	NO
OMP2-7	<200	102,400	YES	NO
OMP2-8-KLH	6,400	51,200	YES	YES
OMP2-8	51,200	3,276,800	YES	YES
OMP2-9-KLH	<200	6,400	YES	NO
OMP2-9	<200	409,600	YES	NO
OMP2-10-KLH	3,200	51,200	YES	YES
OMP2-10	12,800	409,600	YES	YES
OMP2-11-KLH	<200	800	YES	YES
OMP2-11	6,400	102,400	YES	YES
OMP2-12-KLH	51,200	3,276,800	YES	YES
OMP2-12	51,200	32,000	YES	YES
OMP2-13-KLH	<200	<200	NO	NO
OMP2-13	51,200	1,638,400	YES	YES
CHIBP2-KLH	12,800	204,800	YES	NO
CHIBP2	<200	1,600	YES	NO
OMP2-6U-KLH	204,800	3,276,800	YES	YES

[1] The data shown are those obtained with rabbit antisera having The highest antibody titer.

TABLE 10

Immunological properties of rabbit antisera raised against P6 peptides.

IMMUNOGENS	REACTIVE TITER AS DETERMINED BY ELISAS[1]		RECOGNITION OF P6 IN IMMUNOBLOTS	
	NATIVE P6	SPECIFIC PEPTIDES	Hib	NON-TYPEABLE
P6-1	200	6,400	YES	YES
P6-2	1,600	25,600	YES	YES
P6-3	1,600	1,600	YES	YES
P6-4	<50	800	YES	YES
P6-5	800	3,200	YES	YES
P6-6	400	3,200	YES	YES
P6-7	800	12,800	YES	YES

[1] The data shown are those obtained with rabbit antisera having the highest antibody titer.

TABLE 11

IMMUNOLOGICAL PROPERTIES OF P1-P2 HYBRID SYNTHETIC PEPTIDES

IMMUNOGENS	PEPTIDE SEQUENCE	RABBIT ANTI-PEPTIDE AGAINST P1	P2
P1-CP2	VKTIGDKRTLTLNTCARTRTTETGKGVKTEKEKSVGVGLRVYF		
	<---C-P1-----><--------CHIBP2---------->		
IN CFA			
IN ALUM	SEQ ID NO: 42	1/12800 (2/2)	1/6400 (2/2)
		<1/200 (2/2)	1/1600 (1/2)
1P13-2P2	VKTIGDKNTLTLNTFGDGFYAQGYLETRFVTKASENGSNFGDC		
	<---C-P1-----><--------OMP2-2---------->		
IN CFA			
IN ALUM	SEQ ID NO: 43	1/12800 (2/2)	<1/200 (2/2)
		1/12800 (1/2)	<1/200 (2/2)
1P13-2P6	VKTIGDKNTLTLNTCGANYLLAQKREGAKGENKRPNDKAGEV		
	<---C-P1-----><--------OMP2-6---------->		
IN CFA			
IN ALUM	SEQ ID NO: 44	1/6400 (2/2)	1/12800 (2/2)
		<1/200 (2/2)	<1/200 (2/2)
1P13-2P8	VKTIGDKRTLTLNTDIVAKIAYGRTNYKYNESDEHKQQLNGC		
	<---C-P1-----><--------OMP2-8---------->		
IN CFA			
IN ALUM	SEQ ID NO: 45	1/6400 (1/2)	1/12800 (2/2)
		1/3200 (1/2)	1/1600 (1/2)
1P13-2P10	VKTIGDKRTLTLNTYAKTKNYKIKHEKRYFVSPGFQYELC		
	<---C-P1-----><--------OMP2-10--------->		
IN CFA			
IN ALUM	SEQ ID NO: 46	<1/200 (2/2)	1/1600 (1/2)
		<1/200 (2/2)	<1/200 (2/2)
2P2-1P13	GYLETRFVTKASENGSDFKEVKTIGDKRTLTLNTTANYTSQAHANLYGLNLNYSF		
	<-------2P2-----><-------HIBP1-13---------->		
IN CFA			
IN ALUM	SEQ ID NO: 47	1/3200 (1/2)	<1/200 (2/2)
		<1/200 (2/2)	<1/200 (2/2)
2P6-1P13	AKGENKRPNDKAGEVFKEVKTIGDKRTLTLNTTANYTSQAHANLYGLNLNYSF		
	<-------2P6---><-------HIBP1-13---------->		
IN CFA			
IN ALUM	SEQ ID NO: 48	1/12800 (1/2)	1/12800 (1/2)
		1/1600 (1/2)	1/3200 (2/2)
CP2-1P13	ARTRTTETGKGVKTEKFKEVKTIGDKRTLTLNTTANYTSQAHANLYGLNLNYSF		
	<-------CP2----><-------HIBP1-13---------->		
IN CFA			
IN ALUM	SEQ ID NO: 49	1/12800 (1/2)	<1/200 (2/2)
		1/6400 (1/2)	<1/200 (2/2)

TABLE 12

Rabbit Immune Response to Synhtetic $(PRP)_3$-Peptide Conjugates[1]

Immunogens		Anti-PRP IgG ELISA Reactive Titres		
		Pre	2nd Post	3rd Post
HIBP1-4	RB946	<50	<50	1600
	RB947	<50	<50	200
CHIBP1-4	RB5-32	<50	<50	<50
	RB5-33	<50	<50	<50
COMP2-8	RB2-26	<50	800	800
	RB2-27	<50	<50	<50
MAP(COMP2-8)	RB950	<50	400	3200
	RB951	<50	800	3200
P24EC	RB3-28	<50	400	400
	RB3-29	<50	<50	<50

[1] The immunization protocols and the anti-PRP IgG ELISA were performed as described in **Examples 16 and 18.**

CLAIMS

What we claim is:

1. A synthetic peptide having an amino acid sequence corresponding to at least one antigenic determinant of at least one protein of Haemophilus influenzae.

2. The synthetic peptide of claim 1 having an amino acid sequence corresponding to at least one antigenic determinant of an outer membrane protein (OMP) of Haemophilus influenzae.

3. The synthetic peptide of claim 2 wherein said OMP is the P1 protein of Haemophilus influenzae type b and said amino acid sequences is at least one selected from any of the amino acid sequences 1 to 29, 39 to 64, 103 to 137, 165 to 193, 189 to 218, 226 to 253, 248 to 283, 307 to 331, 400 to 437 and 189 to 218 as set forth in Table 1 or a portion or variant of any such sequence which retains immunogenicity.

4. The synthetic peptide of claim 2 wherein said OMP is the P2 protein of Haemophilus influenzae type b and said amino acid sequence is at least one selected from any of the amino acid sequences 1 to 14, 125 to 150, 241 to 265, 263 to 289, 285 to 306, 302 to 319 and 314 to 341 as set forth in Table 2 or a portion or variant of any such sequence which retains immunogenicity.

5. The synthetic peptide of claim 2 wherein said OMP is the P6 protein of Haemophilus influenzae type b and said amino acid sequence is at least one selected from any of the amino acid sequence set forth in Table 3 or a portion or variant of any such sequence which retains immunogenicity.

6. The synthetic peptide of claim 1 having an amino acid sequence corresponding to at least one B-cell epitope of an outer membrane protein (OMP) of Haemophilus influenzae.

7. The synthetic peptide of claim 6 wherein said OMP is the P1 protein of Haemophilus influenzae type b and said

amino acid sequence is at least one selected from any of the amino acid sequences 39 to 64, 103 to 137, 165 to 193, 248 to 283, 307 to 338, 400 to 437 and 197 to 218 set forth in Table 1 or a portion or variant of any such sequence which retains immunogenicity.

8. The synthetic peptide of claim 6 which said OMP is the P2 protein of Haemophilus influenzae type b and said amino acid sequence is at least one selected from any of the amino acid sequences 53 to 81, 148 to 174, 241 to 265 and 314 to 342 set forth in Table 2 or a portion or variant of any such sequence which retains immunogenicity.

9. The synthetic peptide of claim 6 which said OMP is the P6 protein of Haemophilus influenzae type b and said amino acid sequence is at least one selected from any of the amino acid sequences 73 to 96, 90 to 114 and 109 to 134 set forth in Table 2 or a portion or variant of any such sequence which retains immunogenicity.

10. The synthetic peptide of claim 1 having an amino acid sequence corresponding to at least one immunodominant T-cell epitope.

11. The synthetic peptide of claim 10 wherein said T-cell epitope is derived from an outer membran protein of (OMP) of Haemophilus influenzae.

12. The synthetic peptide of claim 11 wherein said OMP is the P1 protein of Haemophilus influenzae type b and said amino acid sequence is selected from any one of the amino acid sequences 39 to 64, 225 to 253, 339 to 370 and 400 to 437 set forth in Table 1 or a portion or variant thereof which retains immunogenicity.

13. The synthetic peptide of claim 11 wherein said OMP is the P2 protein of Haemophilus influenzae type b and said amino acid sequence is selected from any one of the amino acid sequences 125 to 150, 193 to 219, 219 to 244 and 241 to 265 as set forth in Table 2 or a portion or variant thereof which retains immunogenicity.

14. The synthetic peptide of claim 11 which said OMP is the P6 protein of Haemophilus influenzae type b and said amino acid sequence is at least one selected from any of the amino acid sequences 19 to 41, 35 to 58, 73 to 96 and 109 to 134 as set forth in Table 3 or a portion or variant thereof which retains immunogenicity.

15. The synthetic peptide claimed in any one of claims 1 to 14 is modified with lipid to be in the form of a lipopeptide.

16. The synthetic peptide of claim 15 in the form of a synthetic lipopeptide or a mixture of synthetic lipopeptides that, when combined to form molecular aggregates, is capable of inducing mammals to produce an immune response against Haemophilus influenzae.

17. The synthetic peptide of claim 1 comprising at least one T-cell epitope (T) and at least one neutralization B-cell epitope (B).

18. The synthetic peptide of claim 17 in the form of a chimeric T-B peptide.

19. The synthetic peptide of claim 18 comprising at least one T-cell epitope of P1, P2 or P6 protein of Haemophilus influenzae type b and at least one neutralization B-cell epitope of P1, P2 or P6 protein of Haemophilus influenzae type b.

20. The synthetic peptide of claim 18 wherein said chimeric T-B peptide is selected from P1-P2 chimeric synthetic peptides having an amino acid sequence as set forth in Table 11.

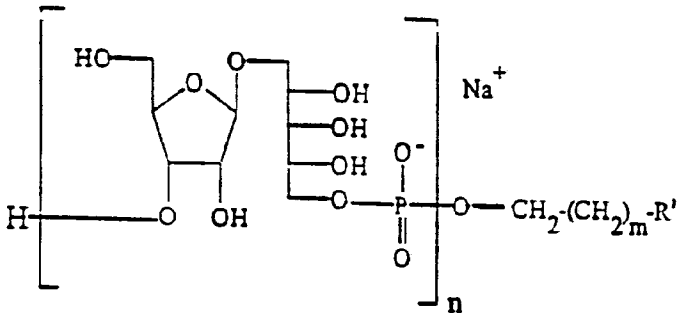
21. The synthetic peptide claimed in any one of claims 1 to 20 which is produced by chemical synthesis or by recombinant procedure.

22. An immunogenic conjugate, comprising a synthetic carbohydrate antigen linked to at least one synthetic T-cell epitope.

23. The conjugate of claim 22, wherein said carbohydrate antigen corresponding to at least a portion of a bacterial, viral or tumor oligosaccharide.

24. The conjugate of claim 23, when said carbohydrate is a synthetic riboseribitol phosphate (PRR) oligomer.

25. The conjugate of claim 24 wherein said synthetic oligosaccharide is a linear homopolymer of alternating molecules of ribose and ribitol joined by a phosphodiester linkage represented by the formula:



wherein n is an integer and m is an integer and R′ is a synthetic peptide containing at least one T-cell epitope.

26. The conjugate of claim 25 wherein said synthetic peptide comprises -(CH_2-Y-carrier) and is capable of enhancing a host immune response to the oligosaccharide moiety, in which the carrier is a peptide containing at least one T-helper epitope and Y is a residue of a bifunctional reactive compound.

27. The conjugate of claim 25 wherein said synthetic peptide contains the amino acid sequence GPKEPFRDYVDRFYK from the HIV-1 gag p24 protein.

28. The conjugate of claim 25 wherein said synthetic peptide has an amino acid sequence corresponding to at least one T-cell epitope or T-B peptide epitope of at least one outer membrane protein (OMP) of Haemophilus influenzae.

29. An immunogenic conjugate, comprising a synthetic peptide having an amino acid sequence corresponding to at least one immunodominant T-cell epitope of at least one

protein of Haemophilus influenzae linked to at least one synthetic B-cell epitope.

30. The conjugate of claim 28 or 29 wherein said OMP is the P1 protein of Haemophilus influenzae type b and said amino acid sequence is at least one selected from the any of the amino acid sequences 39 to 64, 165 to 193, 189 to 218, 226 to 253, 339 to 370 and 400 to 437 as set forth in Table 1 or a portion or variant thereof which retains immunogenicity.

31. The conjugate of claim 28 or 29 wherein said OMP is the P2 protein of Haemophilus influenzae type b and said amino acid sequence is at least one selected from the any of the amino acid sequences 125 to 150, 193 to 219, 219 to 244 and 241 to 265 as set forth in Table 2 or a portion or variant thereof which retains immunogenicity.

32. The conjugate of claim 28 or 29 wherein said OMP is the P6 protein of Haemophilus influenzae type b and said amino acid sequence is at least one selected from the any of the amino acid sequences 19 to 41, 35 to 58, 73 to 96 and 109 to 134 as set forth in Table 3 or a portion or variant thereof which retains immunogenicity.

33. The conjugate of any one of claims 21 to 32 wherein said synthetic peptide is a multiple antigen peptide in which each peptide comprises at least one T-cell epitope.

34. A vaccine against disease caused by a pathogen, comprising at least one synthetic peptide claimed in any one of claims 1 to 21 and/or at least one synthetic conjugate as claimed in any one of claims 22 to 33, and a physiological carrier therefor.

35. The vaccine of claim 34 against disease caused by Haemophilus influenzae.

36. The vaccine of claim 35 against disease caused by Haemophilus influenzae type b.

37. The vaccine of any one of claims 34 to 36 which further comprises at least one other immunogenic and/or immunostimulating molecule.

38. The vaccine of any one of claims 34 to 37 further comprising an adjuvant.

39. The vaccine of any one of claims 34 to 38 wherein the vaccine is formulated a liposome, a microparticle or a capsule.

40. The vaccine of any one of claims 34 to 39 formulated for intramuscular, parenteral or oral administration.

41. The vaccine of any one of claims 34 to 40 further comprising means for delivering said synthetic peptide and/or conjugate specifically to cells of the immune system.

42. The vaccine of claim 41 wherein said delivery means comprising an antibody molecule.

43. The vaccine of any one of claims 34 to 42 wherein said synthetic peptide and/or synthetic conjugate comprise at least one component of a multivalent vaccine.

44. A method of immunizing a host against a disease, which comprises administering to the host an effective amount of a vaccine as claimed in any one of claims 34 to 43.

45. A diagnostic reagent for detecting infection by Haemophilus influenzae comprising at least one synthetic peptide of any one of claims 1 to 20 and/or at least one synthetic conjugate of any one of claims 22 to 33.

46. A method of detecting infection by Haemophilus influenzae in a host, which comprises using a synthetic peptide of any one of claims 1 to 21.

47. An antibody raised against a synthetic peptide of any one of claims 1 to 21 or a synthetic conjugate as claimed in any one of claims 22 to 33.

48. A live vector for antigen delivery containing a gene having a nucleotide sequence coding for an amino acid sequence of the synthetic peptide of any one of claims 1 to 21.

49. The live vector of claim 48 is a viral vector.

50. The live vector of claim 49 wherein said viral vector is selected from poxviral, adenoviral, polioviral and retroviral viral vectors.

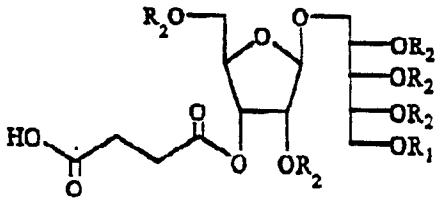
51. The live vector of claim 48 which is a bacterial vector.

52. The live vector of claim 50 wherein said bacterial vector is selected from salmonella and mycobacteria.

53. A vaccine against disease caused by a pathogen, comprising a live vector as claimed in any one of claims 48 to 52, and a physiologically-acceptable carrier therefor.

54. A process for the production of an oligomer, which comprises:

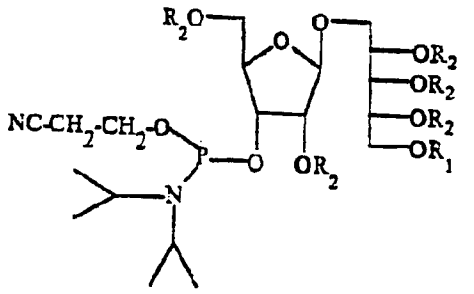
coupling a compound of the formula:



wherein R_1 is a first protecting group and R_2 is a second protecting group, to a solid polyethylene glycol monomethyl ether (PEG) support,

removing said first protecting group,

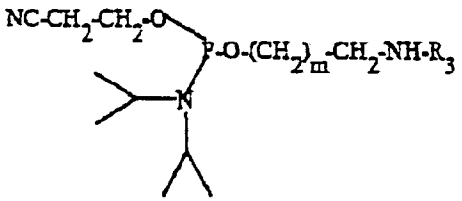
coupling the resulting compound with a repeating unit for chain elongation of the formula:



removing the protecting group from the phosphorus atom,

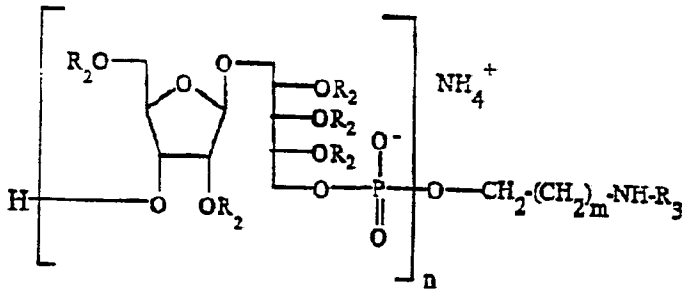
repeating said steps of removing said first protecting group and coupling with the repeating unit until a desired number of repeating units in the oligomer has been assembled,

terminating the oligomer with a chain-terminating molecule of the formula:



wherein m is an integer and R_3 is a third protecting group producing a PEG-bound protected oligomer.

55. The process of claim 54 wherein said PEG-bound protected oligomer is cleaved from said support to provide a compound of the formula:



wherein n is an integer and X^+ is a counter ion, and

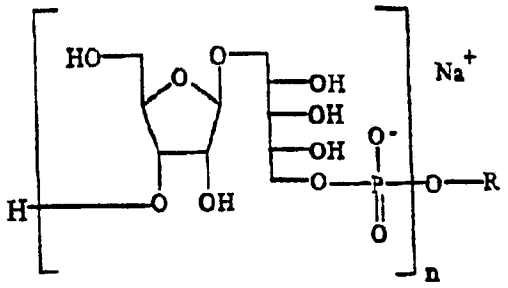
removing said second and third protecting group.

56. The process of claim 55 wherein n is 3 to 20 and m is 4 to 6.

57. The process of claim 56 wherein R_2 is benzyl, R_1 is dimethoxytrityl and R_3 is monomethoxytrityl.

58. The process of claim 57 wherein said counter ion is ammonium.

59. The process of any one of claims 55 to 58 including converting the resulting oligomer to a synthetic PRP oligomer comprising a chemically-reactive functional group represented by the formula:

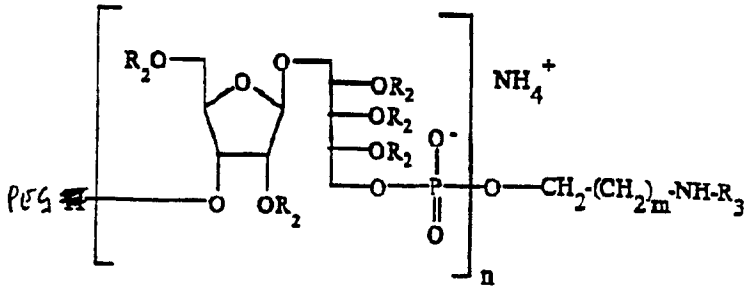


wherein R is a linker fragment.

60. The process of claim 59 wherein said linker fragment has the formula $-CH_2(CH_2)_m-X$ in which m is an integer and X is a chemically-reactive functional group, an amino reactive group or a photoactivatable group.

61. The process of any one of claims 54 to 61 wherein said polyethylene glycol has a loading capacity of about 200 to 500 μmol/g of support.

62. A solid polyethylene glycol monomethyl ether (PEG)-bound protected polysaccharide having the formula:



wherein R_2 and R_3 are protecting groups and m is an integer.

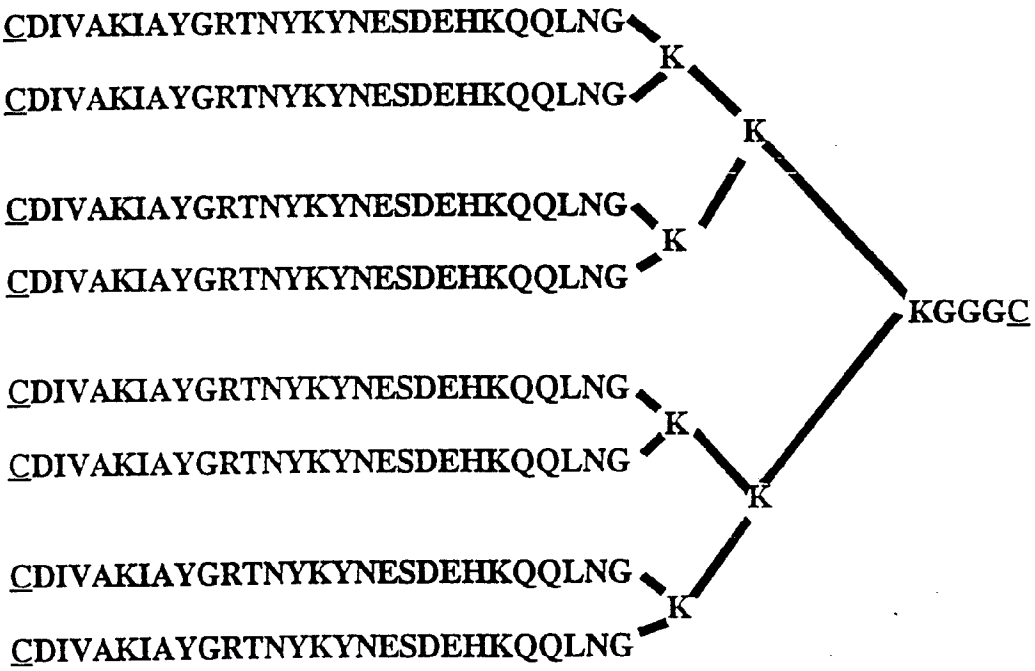
SYNTHETIC PEPTIDES USED IN SYNTHETIC PRP TRIMER CONJUGATION

HIBP1-4 YAKAQVERNAGLIADSVKDNQITSALSTQC

CHIBP1-4 CYAKAQVERNAGLIADSVKDNQITSALSTQ

COMP2-8 CDIVAKIAYGRTNYKYNESDEHKQQLNG

MAP(COMP2-8)



CP6-6 CVKGYLAGYLAGKGVDAGKLGTVSYG

P24EC GPKEPFRDYVDRFYKC

FIGURE 1

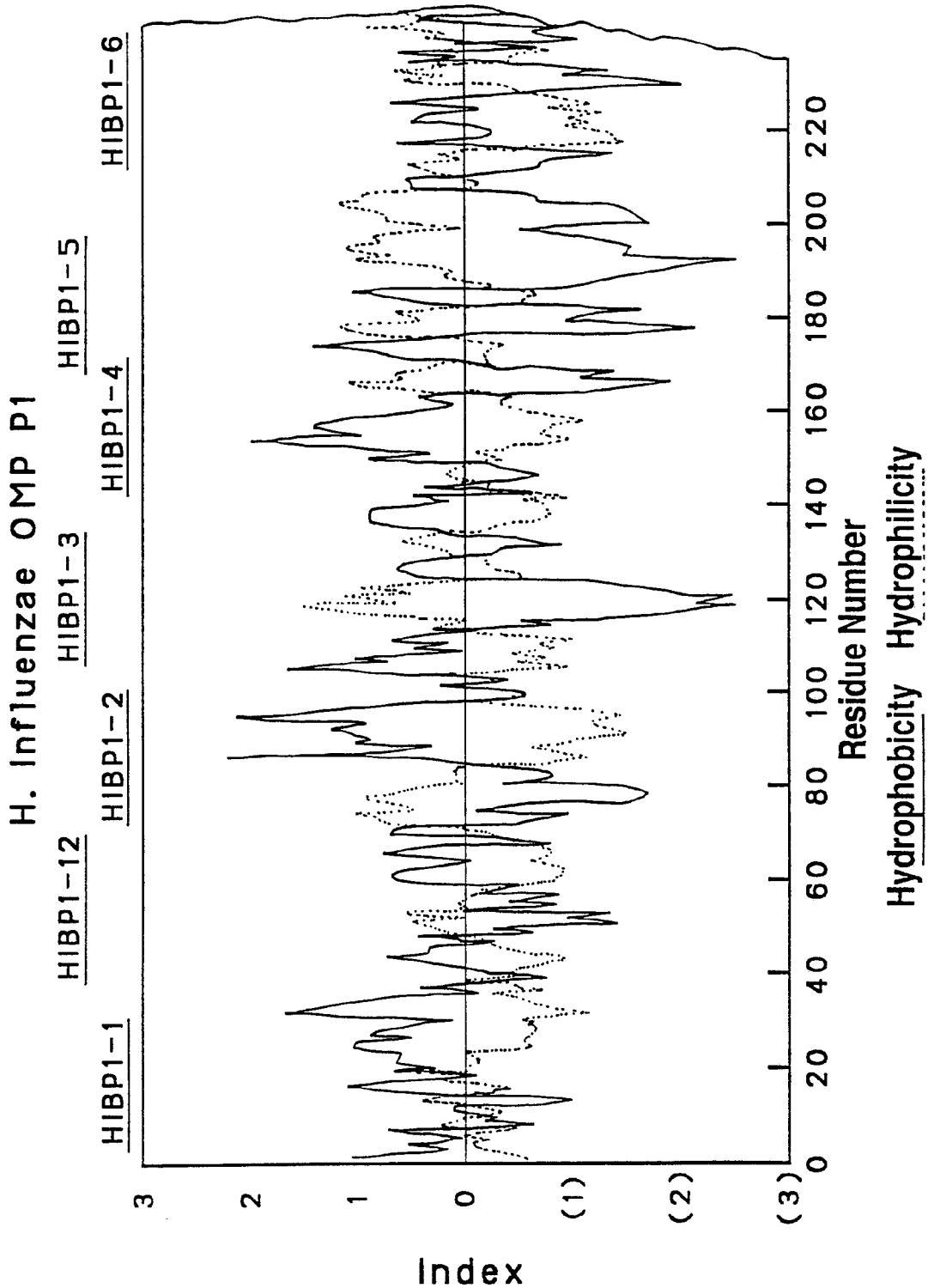

H. Influenzae OMP P1
HIBP1-1
HIBP1-12
HIBP1-2
HIBP1-3
HIBP1-4
HIBP1-5
HIBP1-6
3
2
1
0
(1)
(2)
(3)
Index
0 20 40 60 80 100 120 140 160 180 200 220
Residue Number
Hydrophobicity Hydrophilicity

FIG.2A.

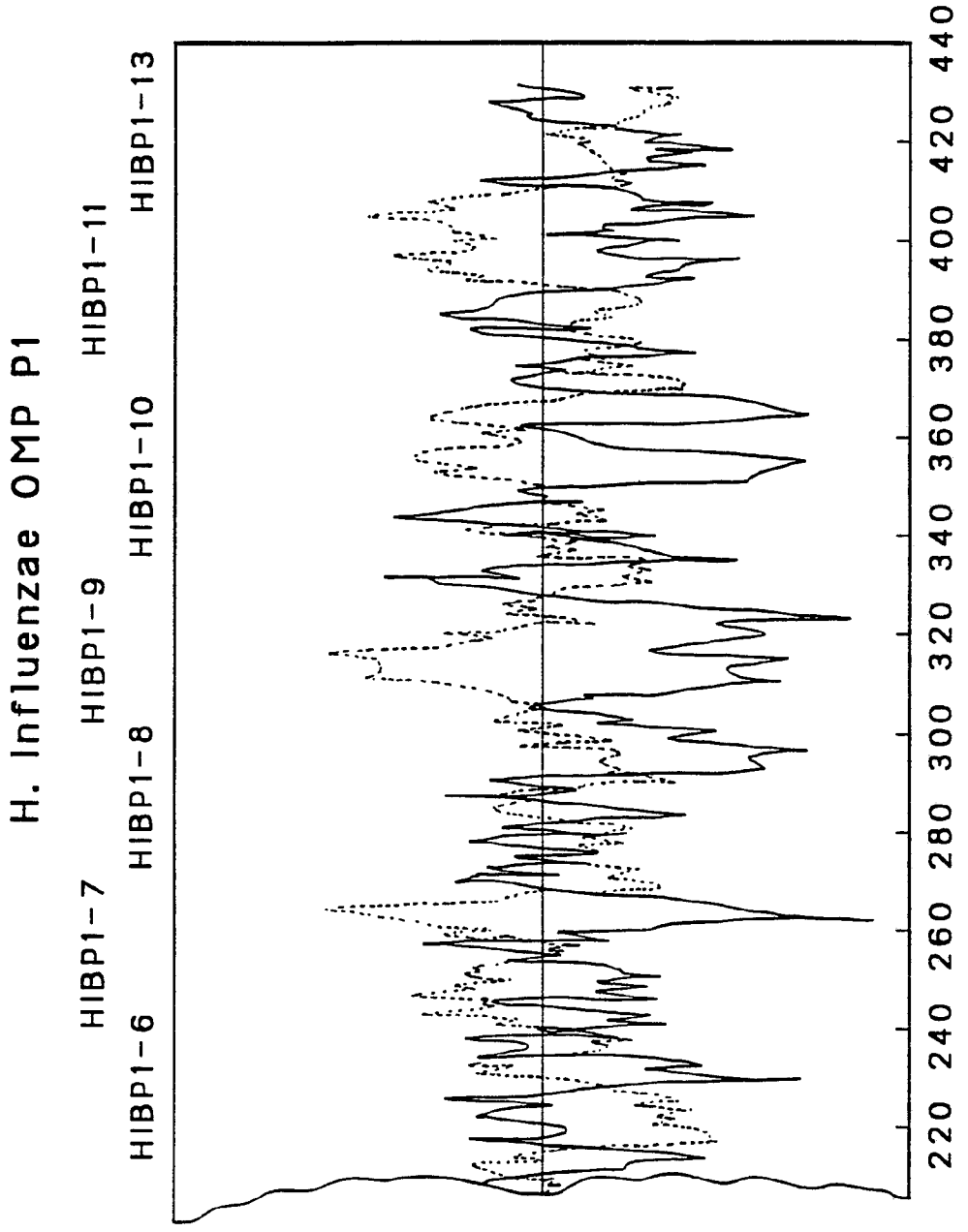

H. Influenzae OMP P1
HIBP1-6
HIBP1-7
HIBP1-8
HIBP1-9
HIBP1-10
HIBP1-11
HIBP1-13
220 240 260 280 300 320 340 360 380 400 420 440
Residue Number
Hydrophobicity Hydrophilicity

FIG.2B.

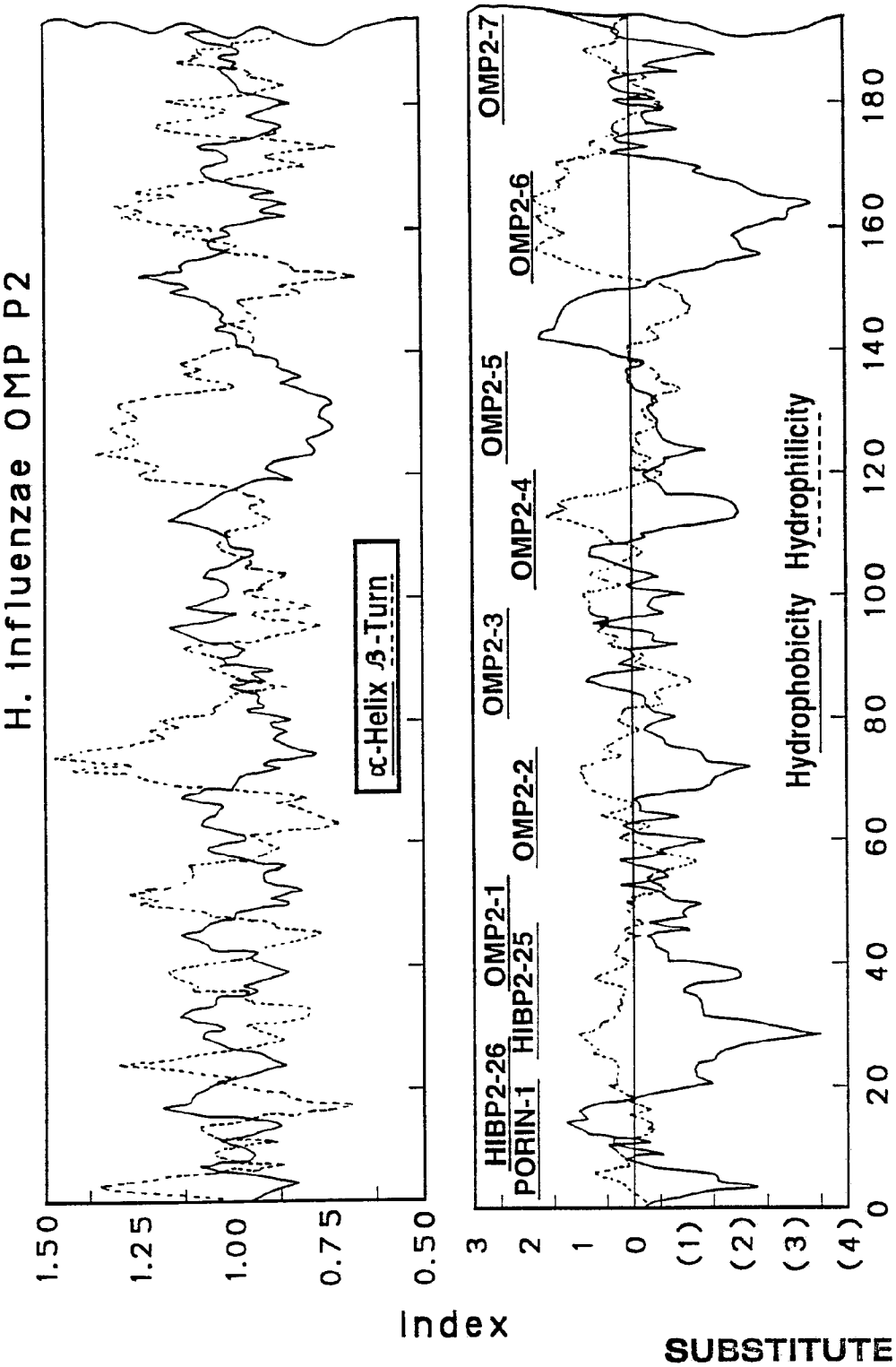

H. Influenzae OMP P2
α-Helix β-Turn
1.50
1.25
1.00
0.75
0.50
Index
HIBP2-26
PORIN-1
OMP2-1
HIBP2-25
OMP2-2
OMP2-3
OMP2-4
OMP2-5
OMP2-6
OMP2-7
Hydrophobicity
Hydrophilicity
3
2
1
0
(1)
(2)
(3)
(4)
0
20
40
60
80
100
120
140
160
180
Residue Number

FIG.3A.

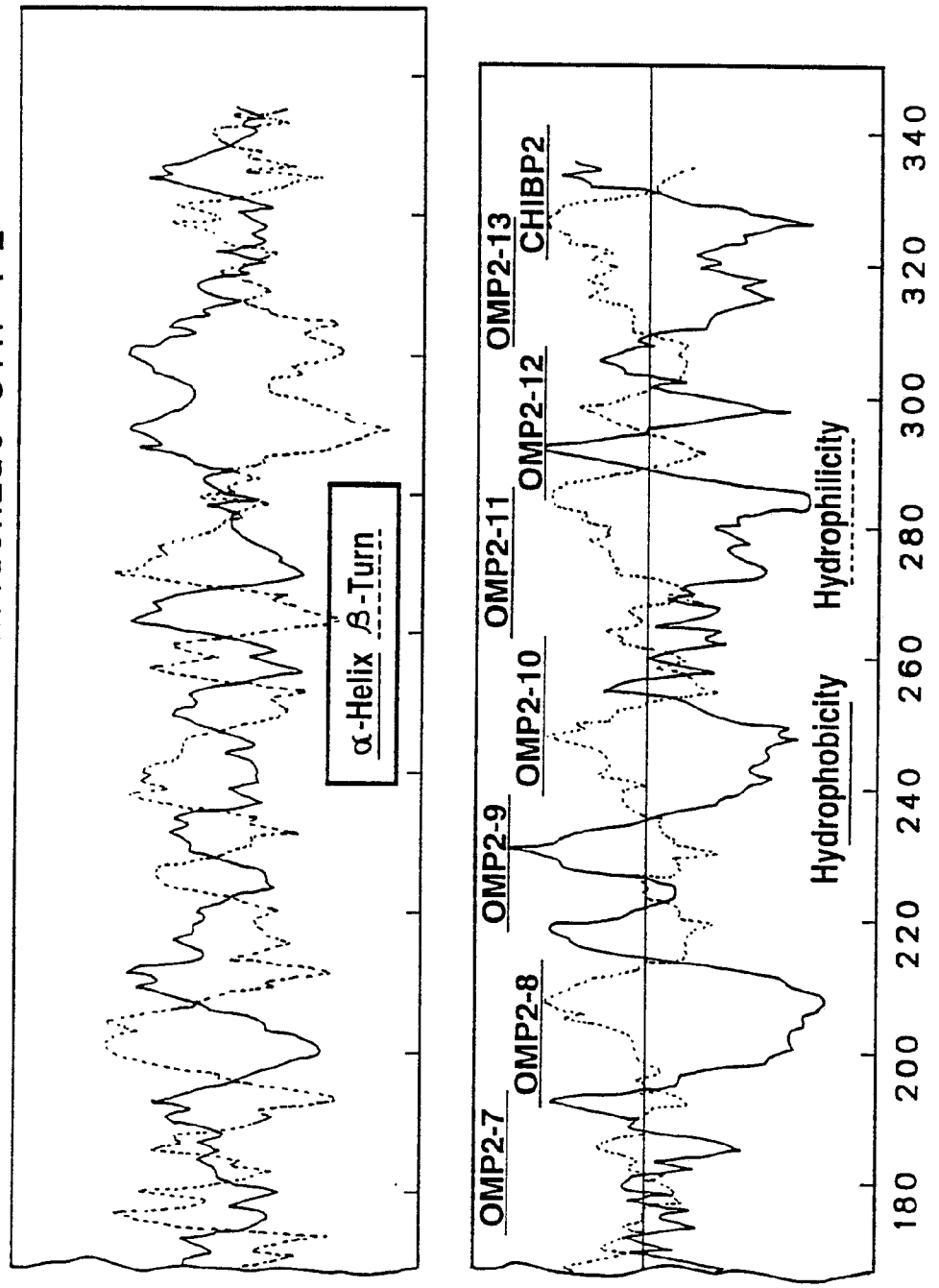

H. Influenzae OMP P2
α-Helix β-Turn
OMP2-7
OMP2-8
OMP2-9
OMP2-10
OMP2-11
OMP2-12
OMP2-13
CHIBP2
Hydrophobicity
Hydrophilicity
180
200
220
240
260
280
300
320
340
Residue Number

FIG.3B.

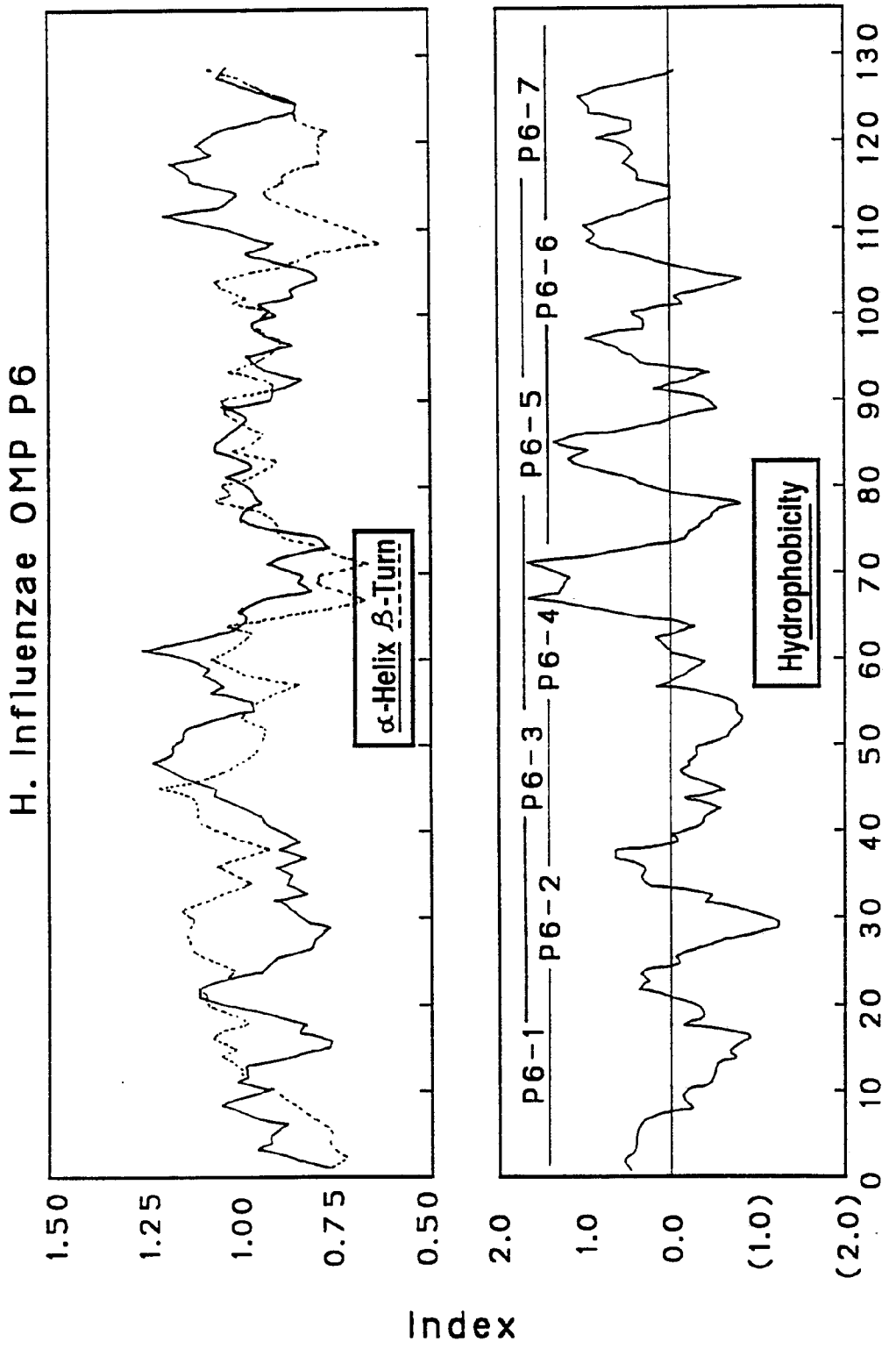

H. Influenzae OMP P6
α-Helix β-Turn
Hydrophobicity
P6-1
P6-2
P6-3
P6-4
P6-5
P6-6
P6-7
1.50
1.25
1.00
0.75
0.50
2.0
1.0
0.0
(1.0)
(2.0)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
Index
Residue Number

FIG.4.

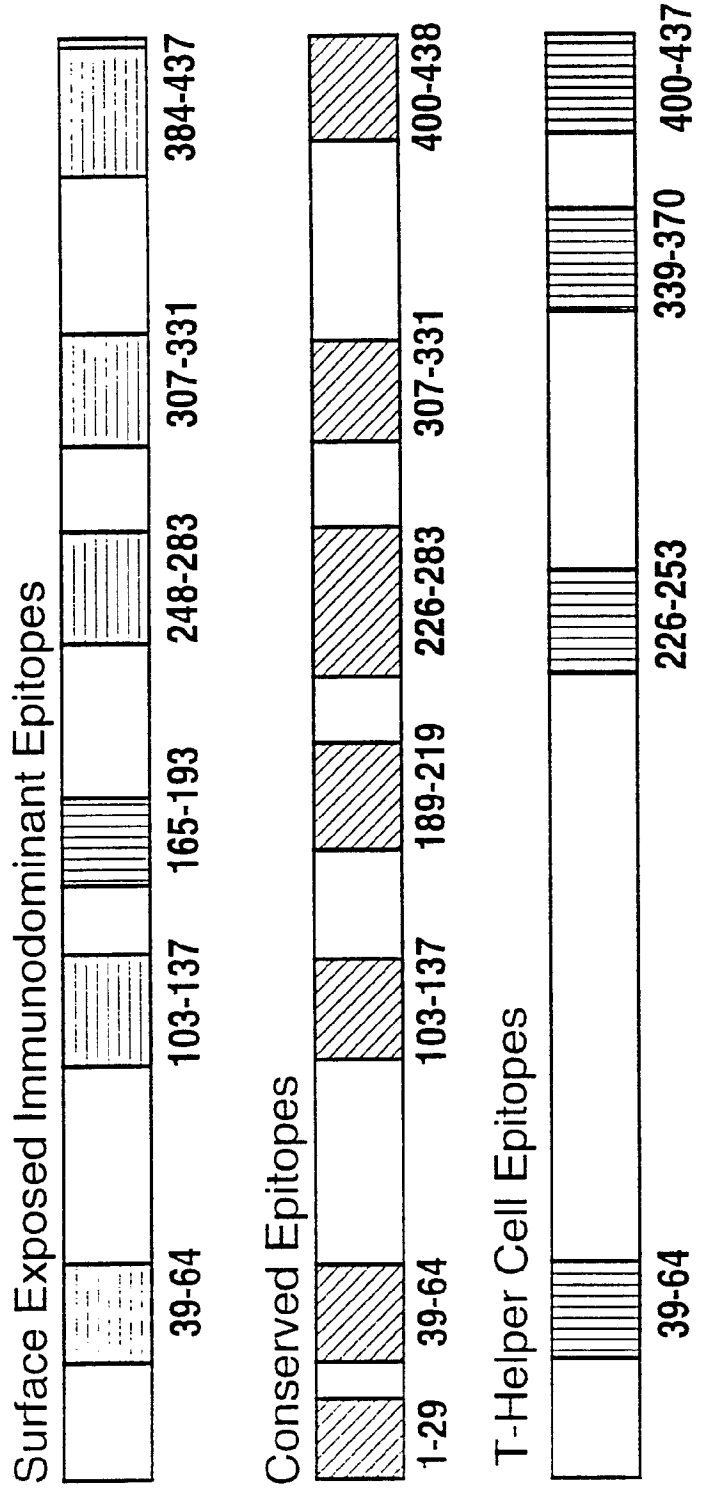

EPITOPE MAPPING OF OMP-P1
Surface Exposed Immunodominant Epitopes
39-64
103-137
165-193
248-283
307-331
384-437
Conserved Epitopes
1-29
39-64
103-137
189-219
226-283
307-331
400-438
T-Helper Cell Epitopes
39-64
226-253
339-370
400-437

FIG.5.

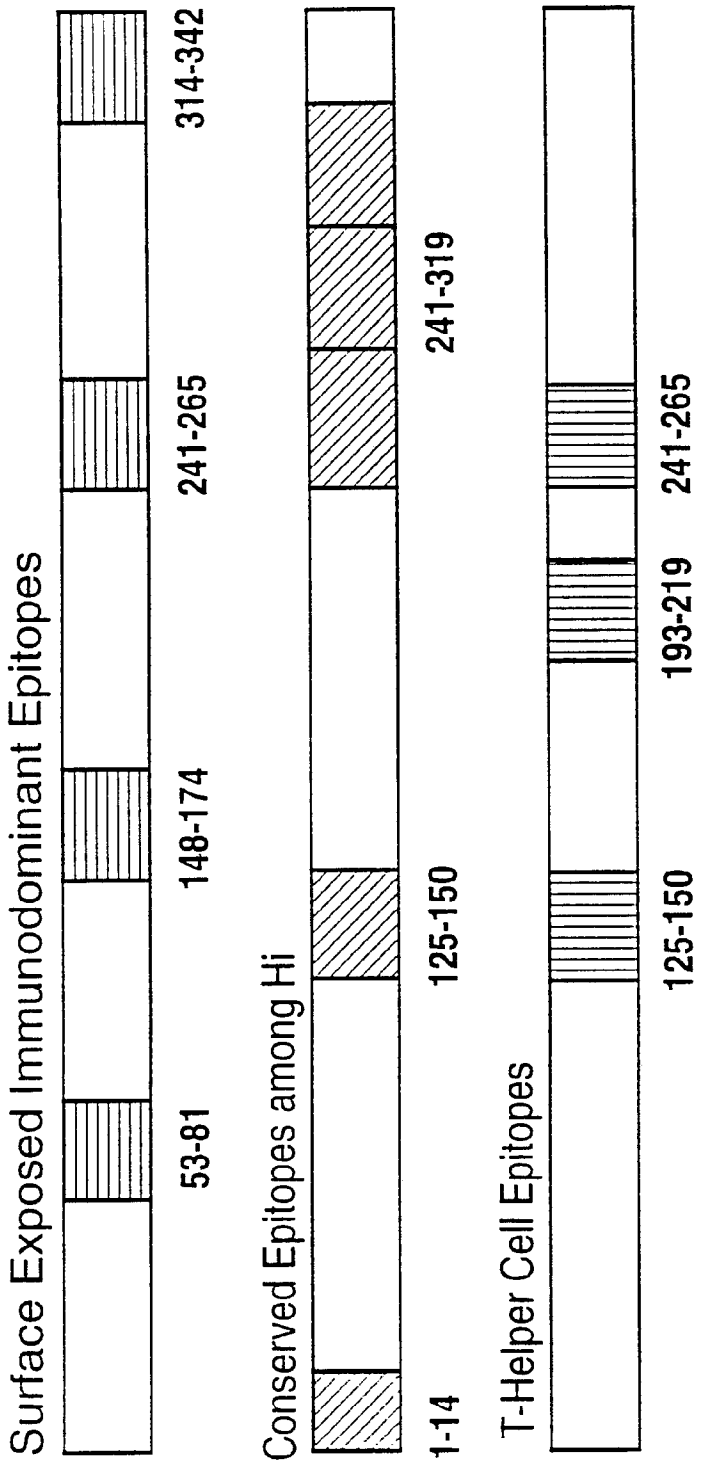

EPITOPE MAPPING OF OMP-P2
Surface Exposed Immunodominant Epitopes
53-81
148-174
241-265
314-342
Conserved Epitopes among Hi
1-14
125-150
241-319
T-Helper Cell Epitopes
125-150
193-219
241-265

FIG.6.

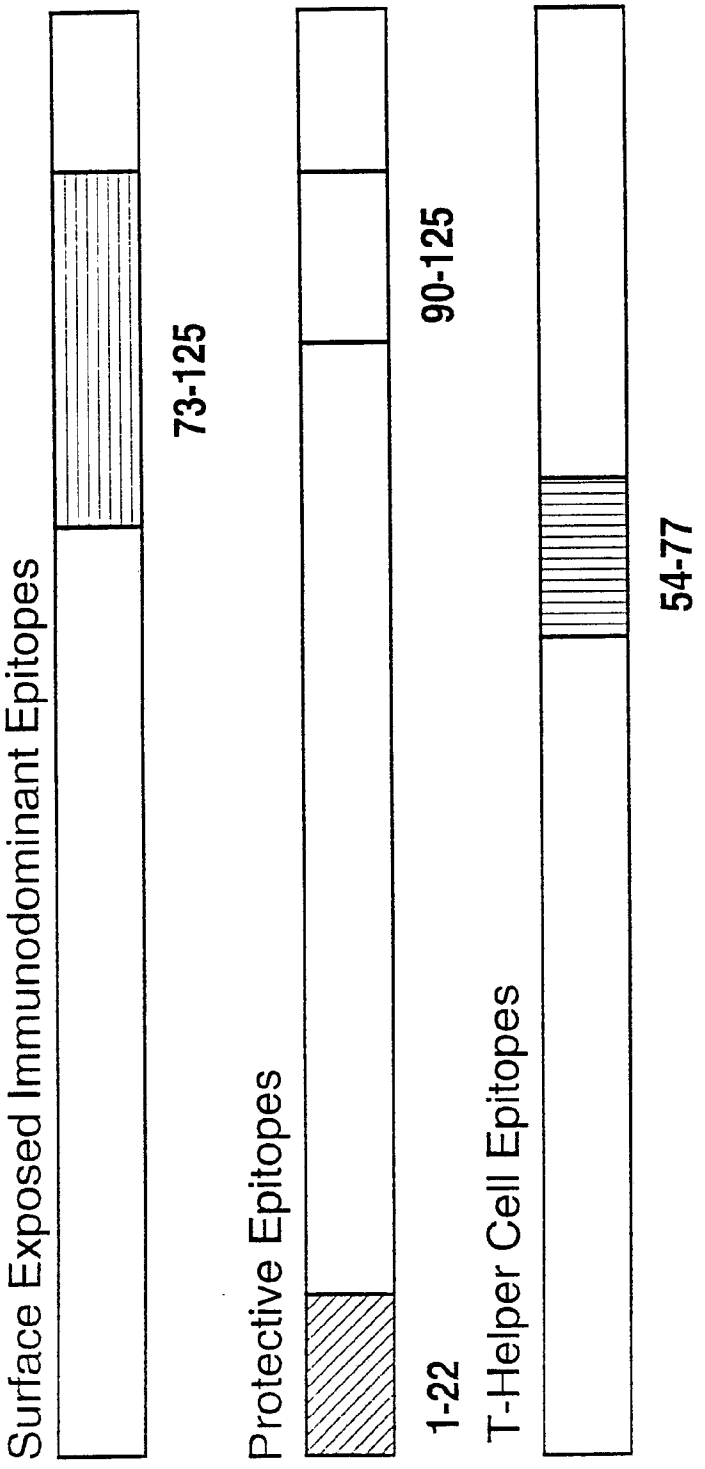

EPITOPE MAPPING OF OMP-P6
Surface Exposed Immunodominant Epitopes
73-125
Protective Epitopes
90-125
1-22
T-Helper Cell Epitopes
54-77

FIG. 7.

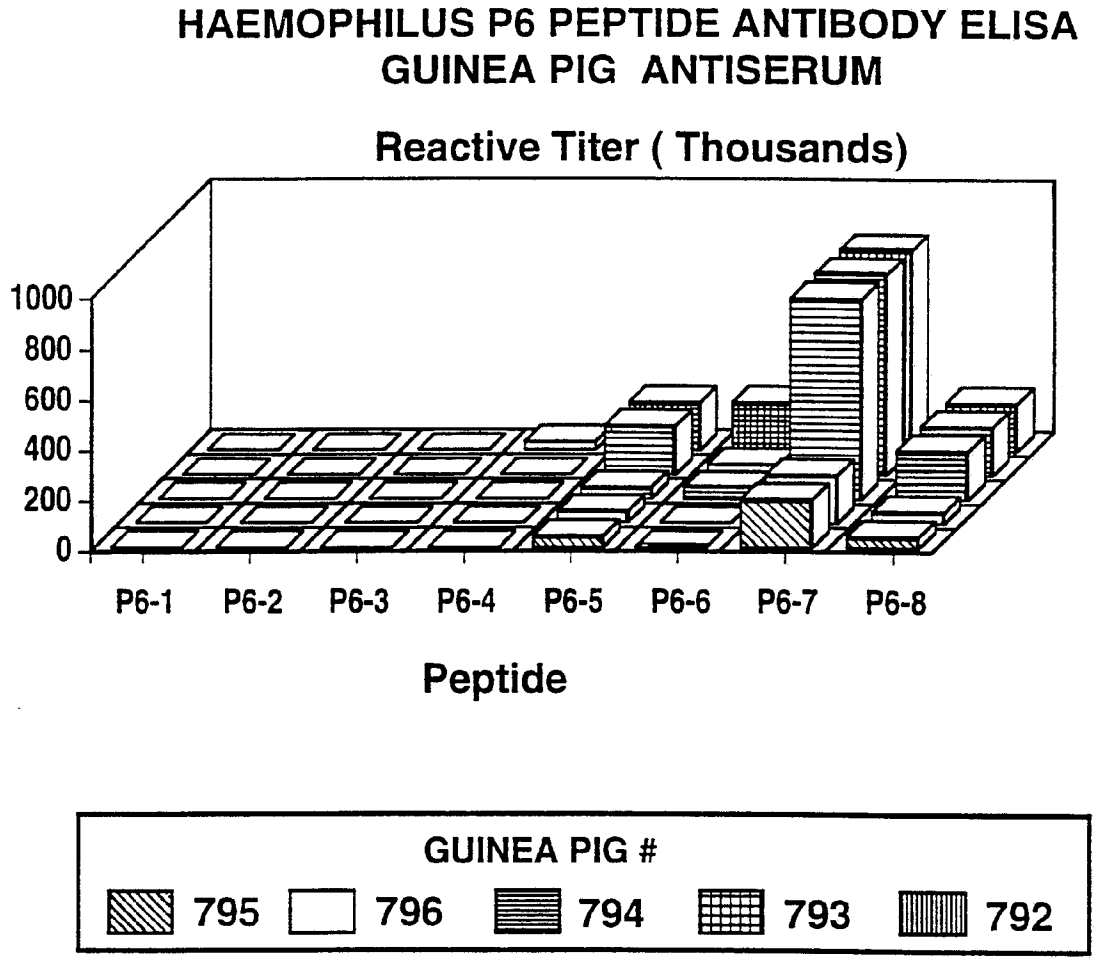

HAEMOPHILUS P6 PEPTIDE ANTIBODY ELISA
GUINEA PIG ANTISERUM
Reactive Titer (Thousands)
1000
800
600
400
200
0
P6-1
P6-2
P6-3
P6-4
P6-5
P6-6
P6-7
P6-8
Peptide
GUINEA PIG #
795
796
794
793
792

FIG.8A.

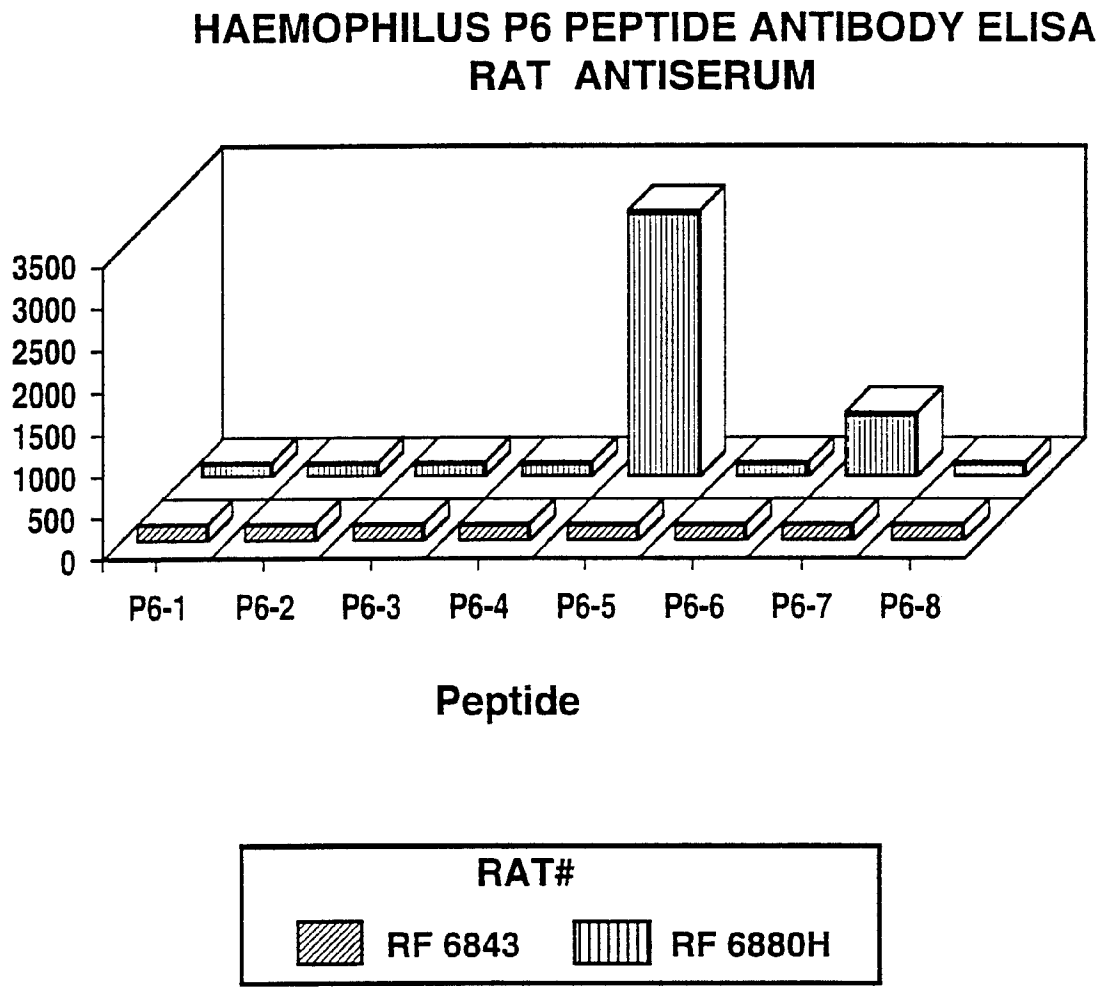

HAEMOPHILUS P6 PEPTIDE ANTIBODY ELISA
RAT ANTISERUM
3500
3000
2500
2000
1500
1000
500
0
P6-1
P6-2
P6-3
P6-4
P6-5
P6-6
P6-7
P6-8
Peptide
RAT#
RF 6843
RF 6880H

FIG.8B.

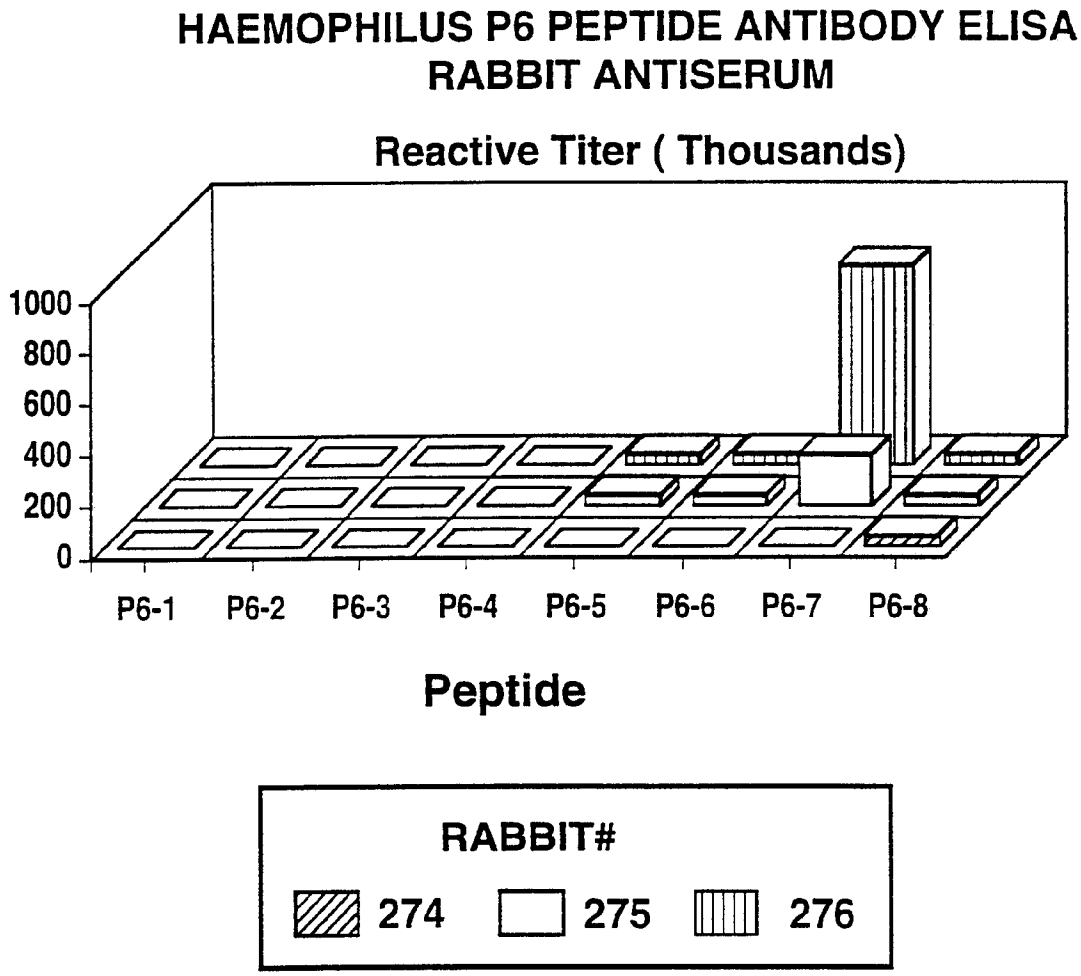

HAEMOPHILUS P6 PEPTIDE ANTIBODY ELISA
RABBIT ANTISERUM
Reactive Titer (Thousands)
1000
800
600
400
200
0
P6-1
P6-2
P6-3
P6-4
P6-5
P6-6
P6-7
P6-8
Peptide
RABBIT#
274
275
276

FIG.8C.

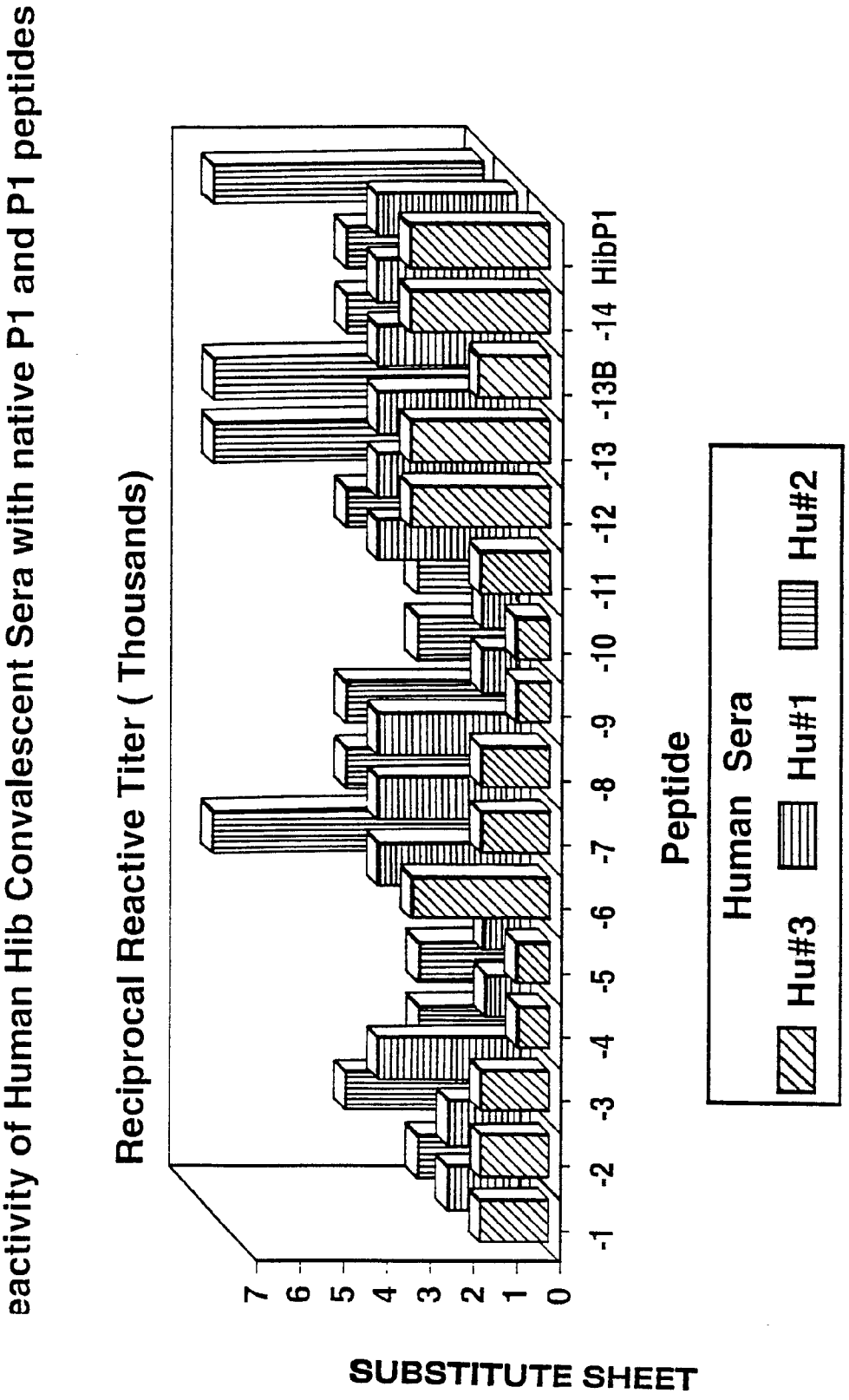

eactivity of Human Hib Convalescent Sera with native P1 and P1 peptides
Reciprocal Reactive Titer (Thousands)
0
1
2
3
4
5
6
7
-1 -2 -3 -4 -5 -6 -7 -8 -9 -10 -11 -12 -13 -13B -14 HibP1
Peptide
Human Sera
Hu#3 Hu#1 Hu#2

FIG.9

Reactivity of Human Hib Convalescent Sera with native P2 and P2 peptides

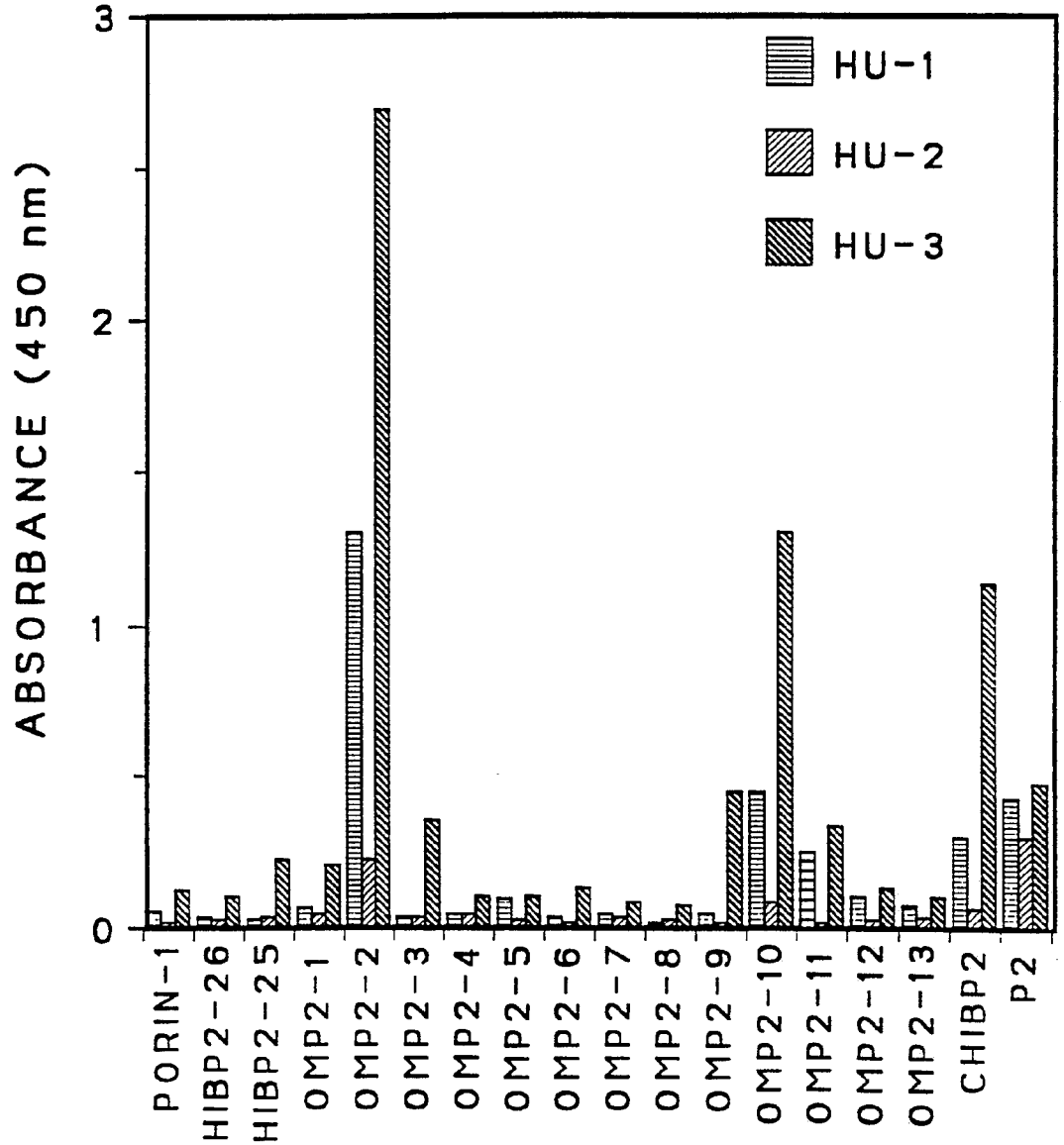


FIG.10.

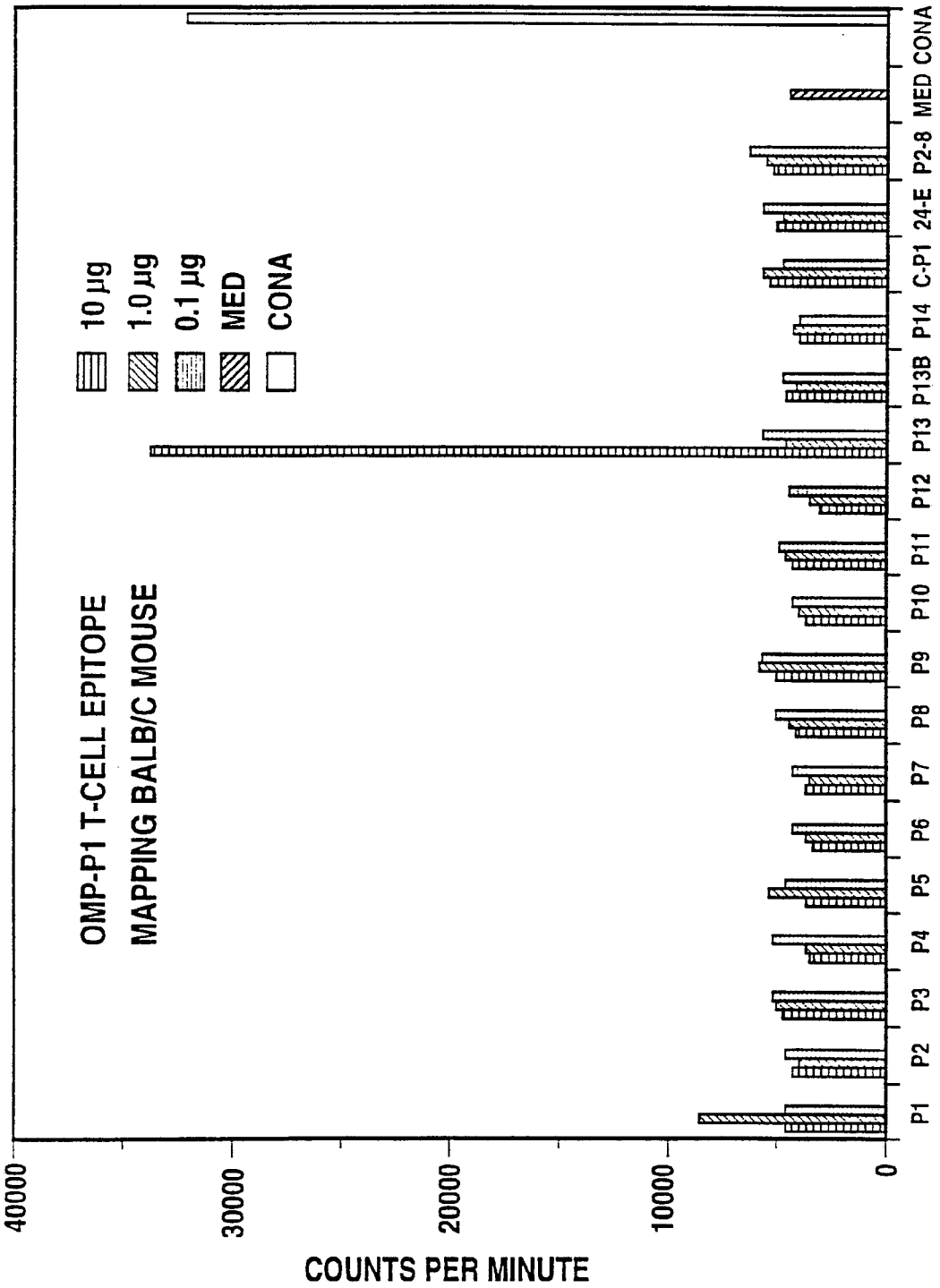

OMP-P1 T-CELL EPITOPE
MAPPING BALB/C MOUSE
10 µg
1.0 µg
0.1 µg
MED
CONA
40000
30000
20000
10000
0
COUNTS PER MINUTE
P1
P2
P3
P4
P5
P6
P7
P8
P9
P10
P11
P12
P13
P13B
P14
C-P1
24-E
P2-8
MED CONA
PEPTIDE

FIG.11A.

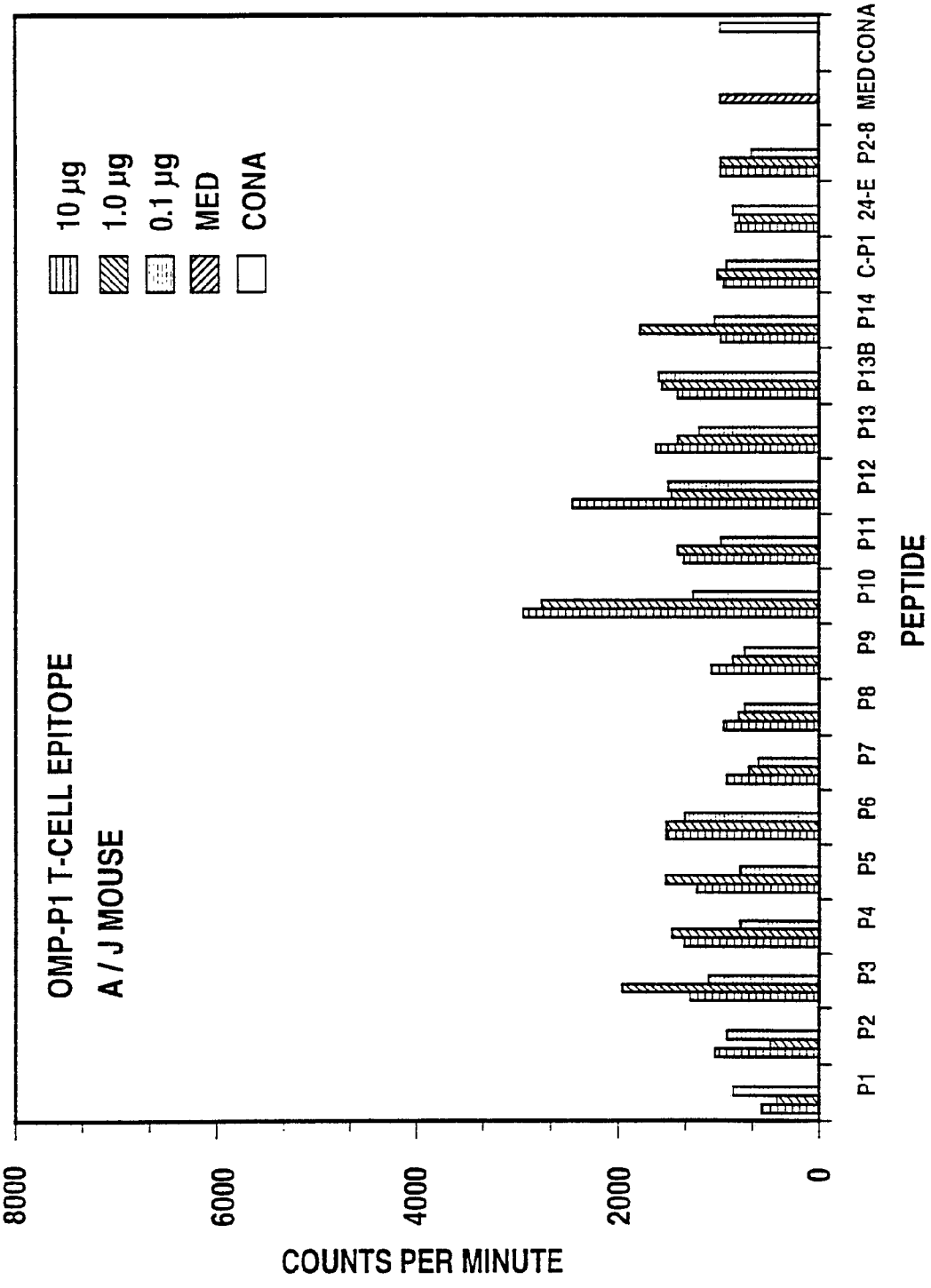

OMP-P1 T-CELL EPITOPE
A/J MOUSE
10 µg
1.0 µg
0.1 µg
MED
CONA
8000
6000
4000
2000
0
COUNTS PER MINUTE
P1
P2
P3
P4
P5
P6
P7
P8
P9
P10
P11
P12
P13
P13B
P14
C-P1
24-E
P2-8
MED
CONA
PEPTIDE

FIG.11B.

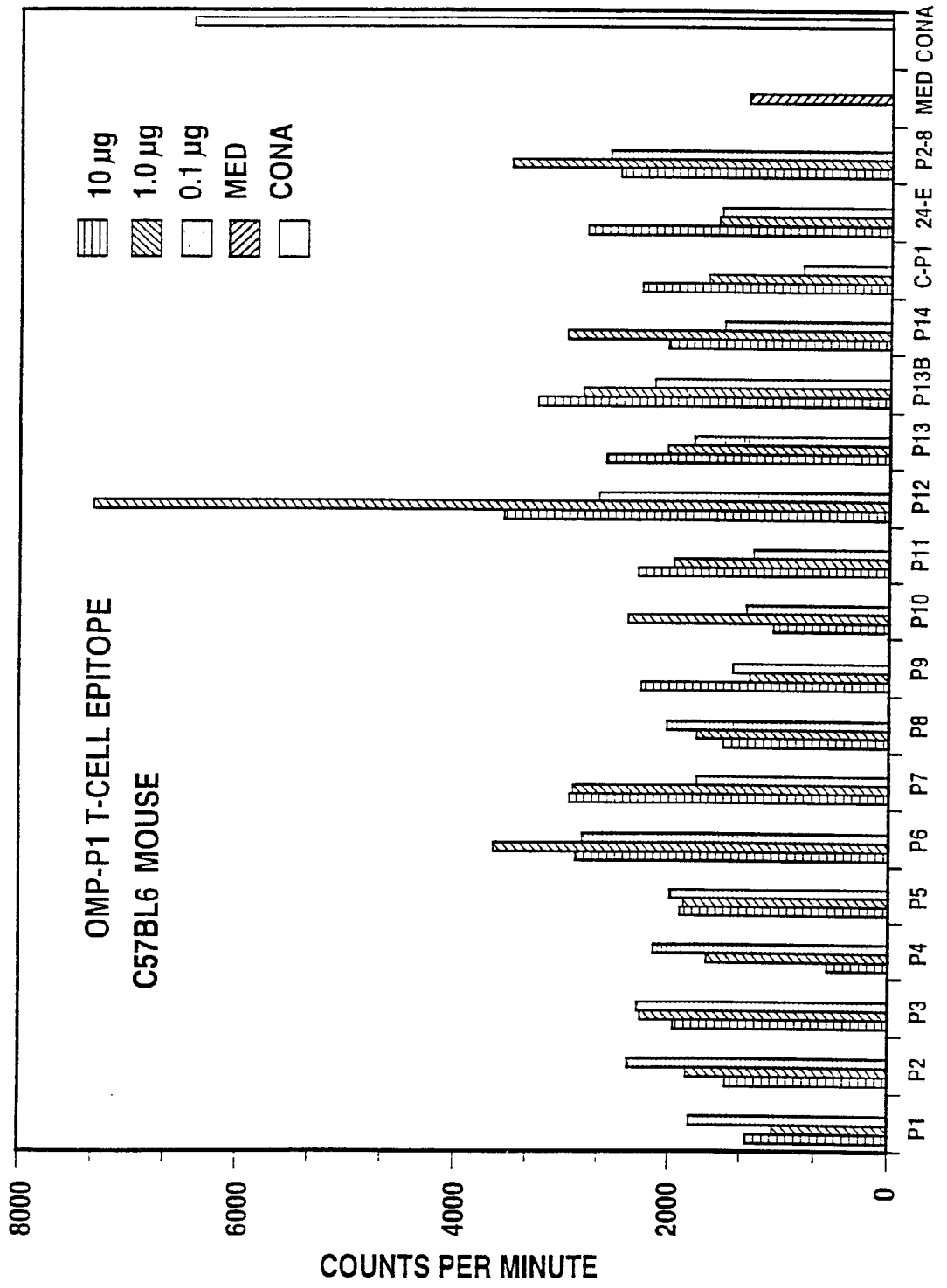

OMP-P1 T-CELL EPITOPE
C57BL6 MOUSE
10 µg
1.0 µg
0.1 µg
MED
CONA
COUNTS PER MINUTE
0
2000
4000
6000
8000
P1
P2
P3
P4
P5
P6
P7
P8
P9
P10
P11
P12
P13
P13B
P14
C-P1
24-E
P2-8
MED CONA
PEPTIDE

FIG.11C.

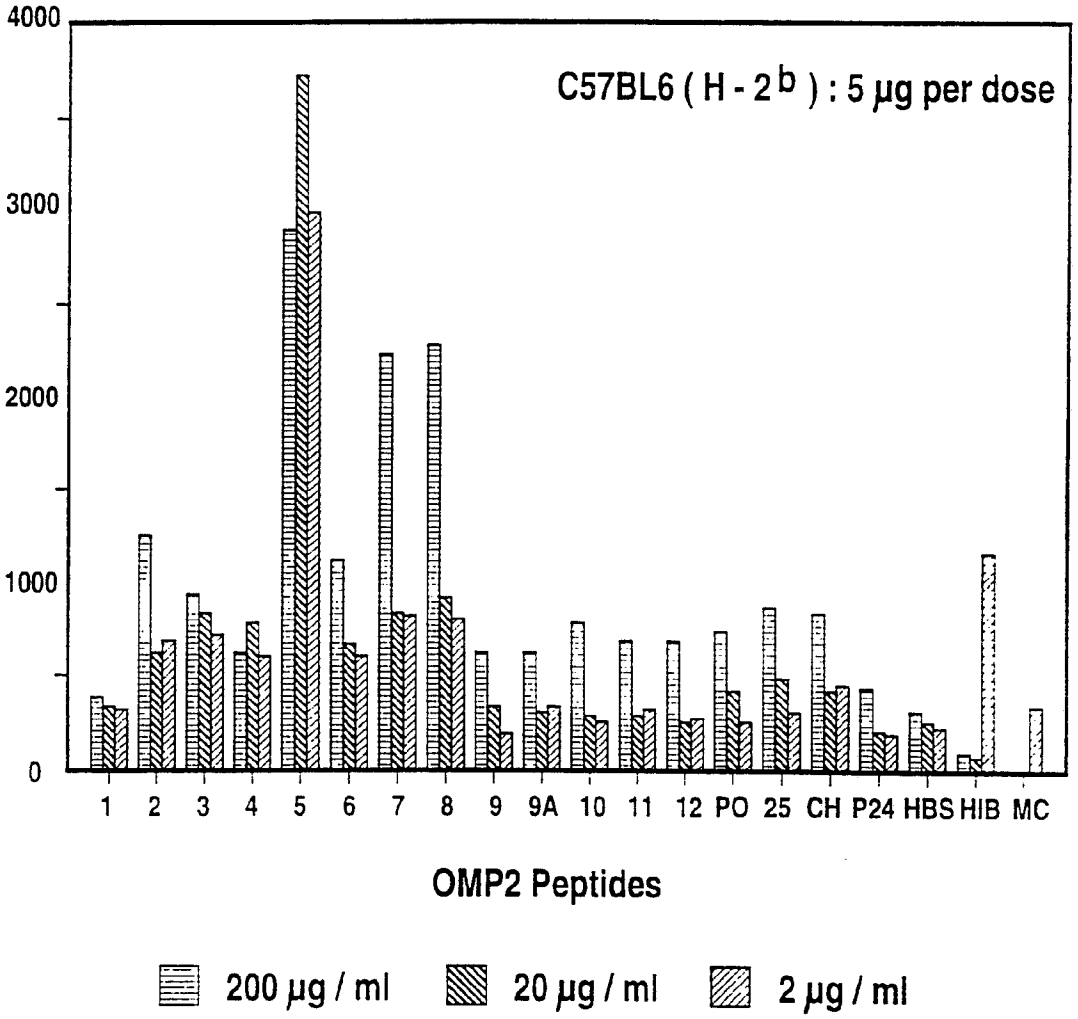

4000
3000
2000
1000
0
C57BL6 (H - 2 b) : 5 µg per dose
1 2 3 4 5 6 7 8 9 9A 10 11 12 PO 25 CH P24 HBS HIB MC
OMP2 Peptides
200 µg / ml
20 µg / ml
2 µg / ml

FIG.12A.

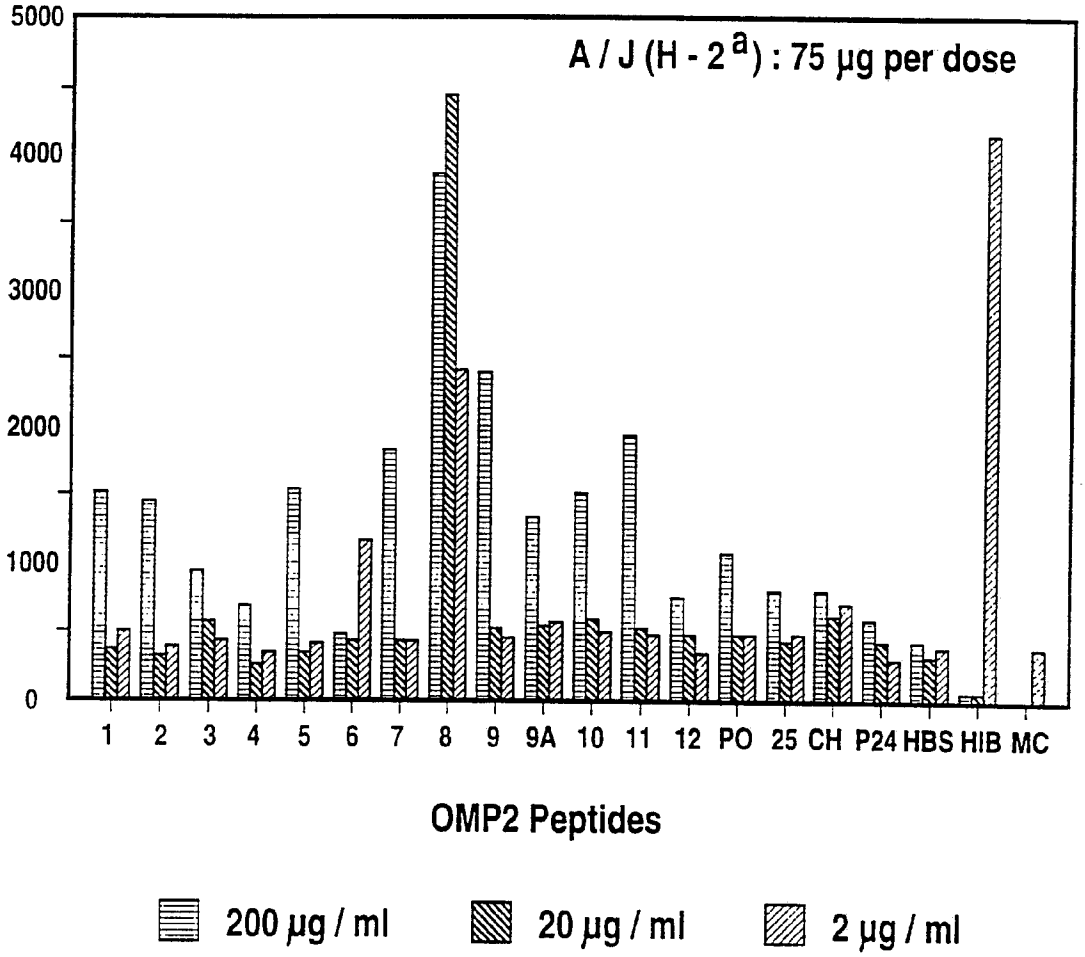

A / J (H - 2 a) : 75 µg per dose
5000
4000
3000
2000
1000
0
1 2 3 4 5 6 7 8 9 9A 10 11 12 PO 25 CH P24 HBS HIB MC
OMP2 Peptides
200 µg / ml
20 µg / ml
2 µg / ml

FIG.12B.

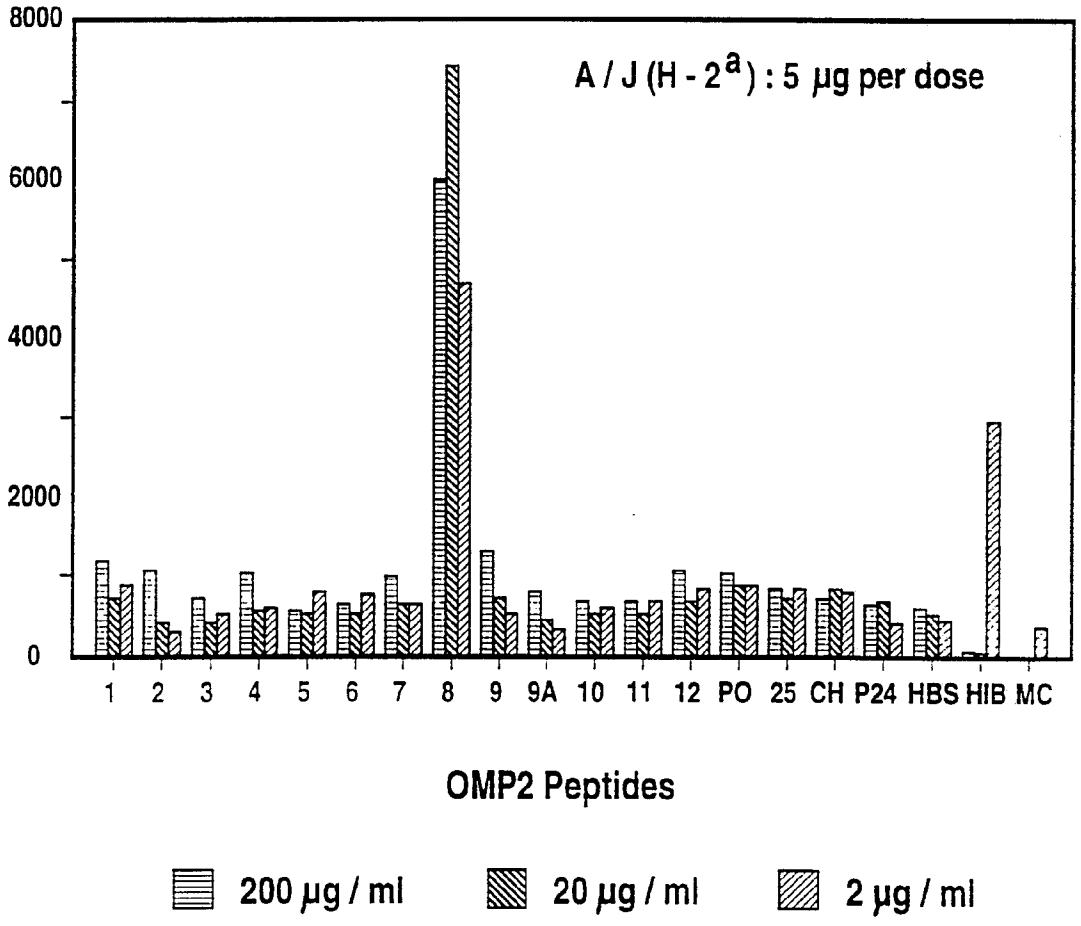

8000
6000
4000
2000
0
A / J (H - 2a) : 5 µg per dose
1 2 3 4 5 6 7 8 9 9A 10 11 12 PO 25 CH P24 HBS HIB MC
OMP2 Peptides
200 µg / ml
20 µg / ml
2 µg / ml

FIG.12C.

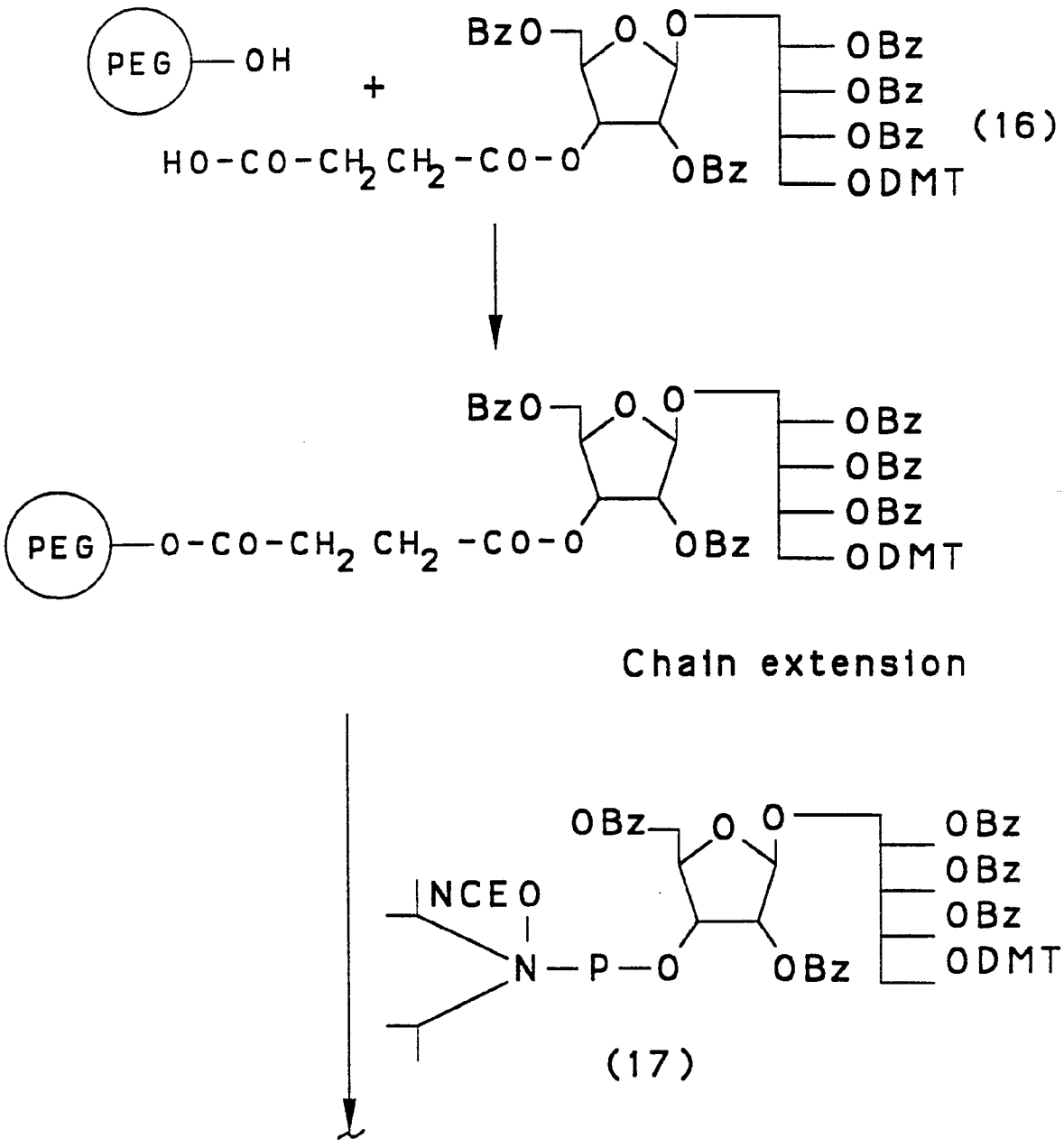

PEG
OH
+
HO-CO-CH2 CH2-CO-O
BzO
O
O
OBz
OBz
OBz
OBz
ODMT
(16)
PEG
O-CO-CH2 CH2 -CO-O
Chain extension
NCEO
N
P
O
(17)

FIG.13A.

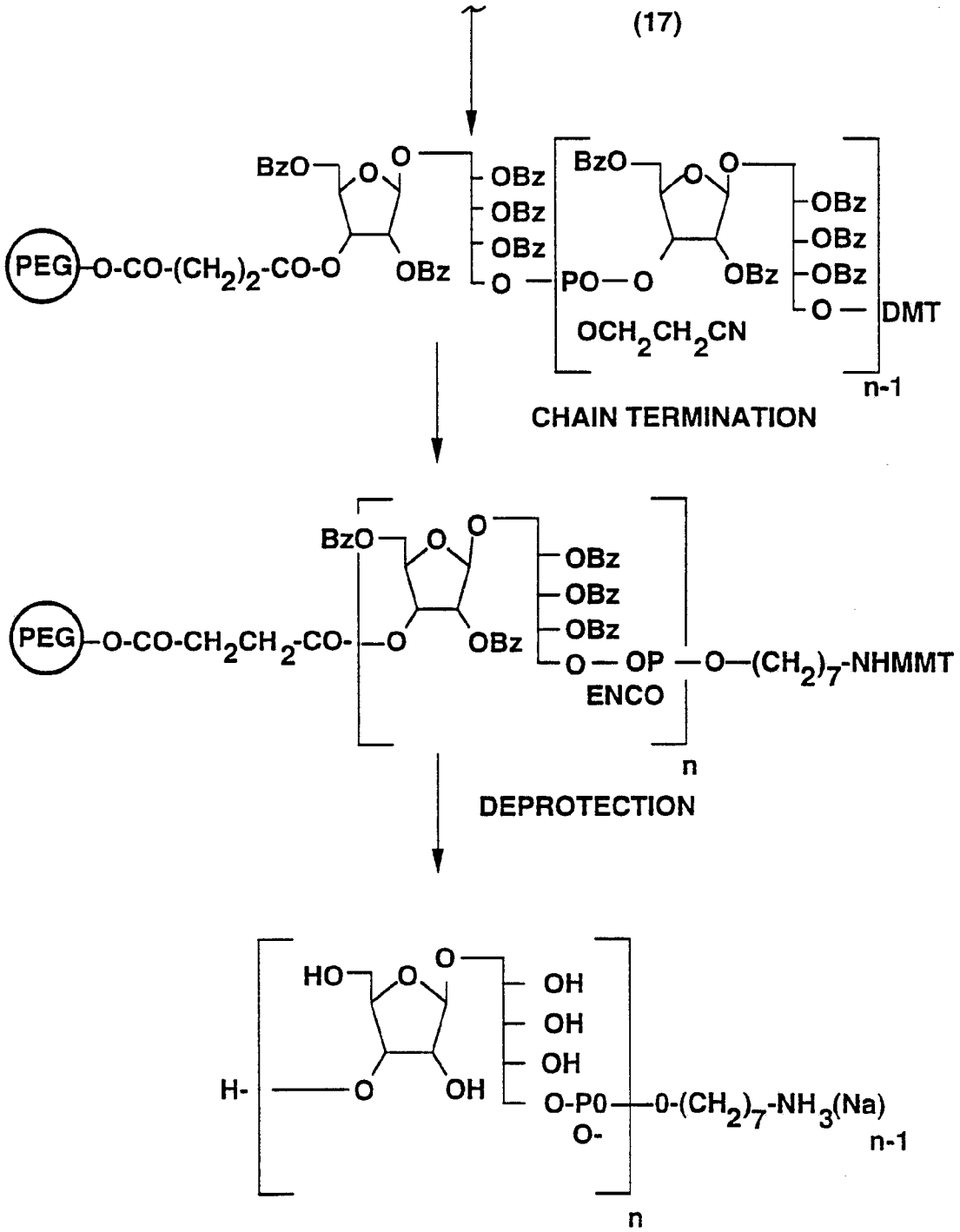

(17)
BzO
OBz
OBz
OBz
O
PO—O
OCH2CH2CN
DMT
n-1
PEG
O-CO-(CH2)2-CO-O
CHAIN TERMINATION
O-CO-CH2CH2-CO-
ENCO
O—(CH2)7-NHMMT
n
DEPROTECTION
HO
OH
H-
O-P0
O-
0-(CH2)7-NH3(Na)

FIG.13B.

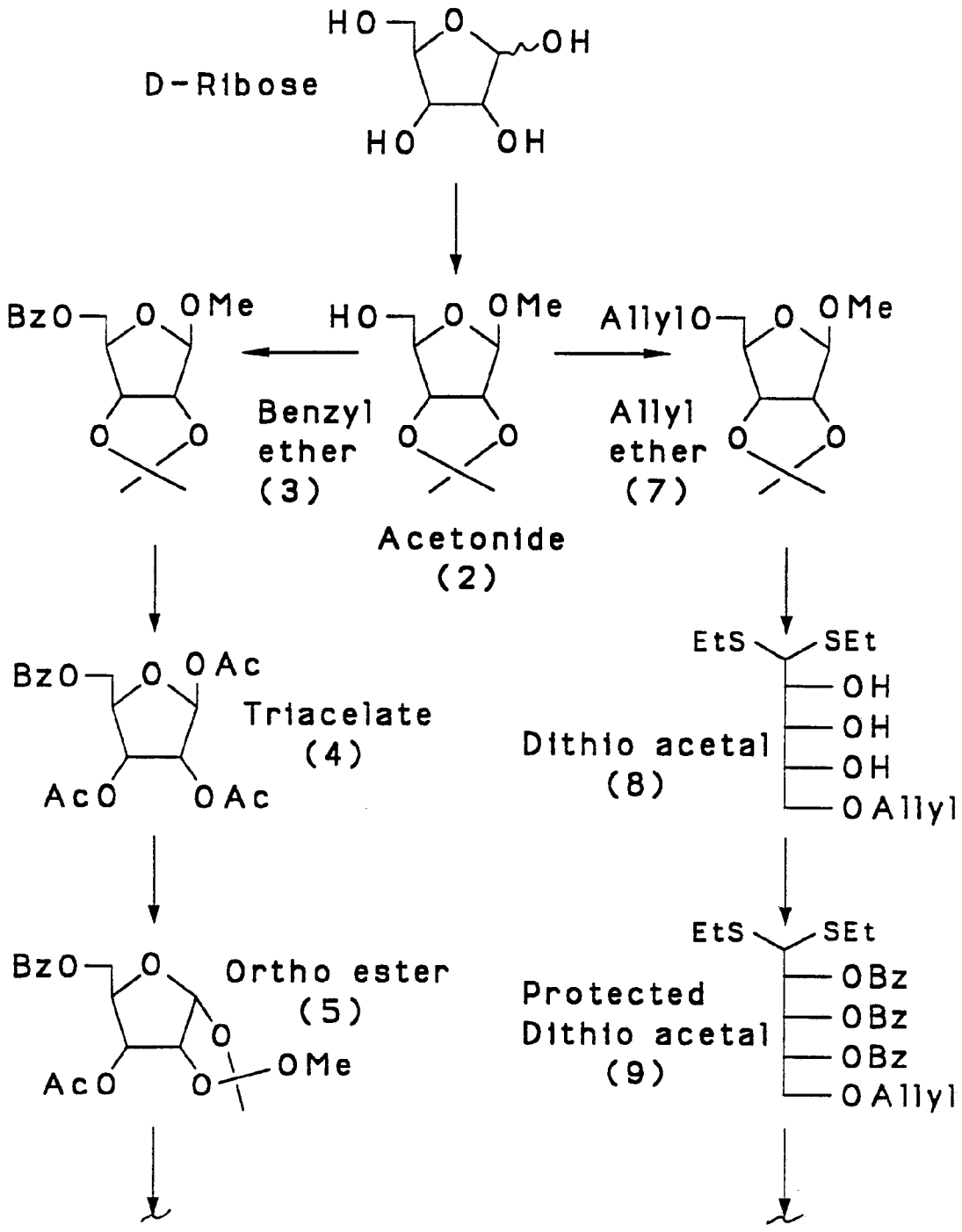
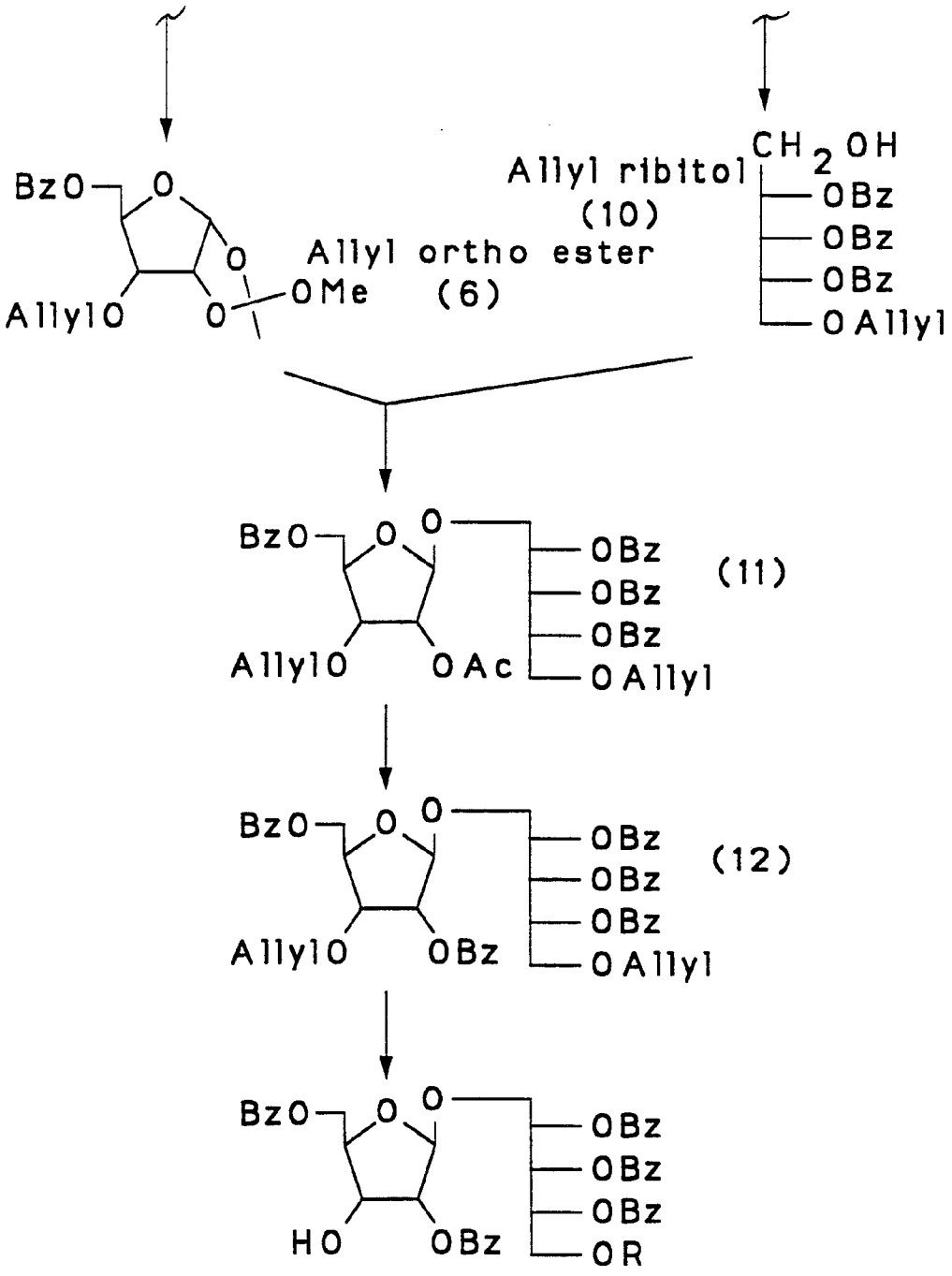

D-Ribose
HO
OH
HO
OH
BzO
OMe
HO
OMe
AllylO
OMe
Benzyl ether (3)
Allyl ether (7)
Acetonide (2)
BzO
OAc
Triacelate (4)
AcO
OAc
EtS
SEt
OH
OH
OH
OAllyl
Dithio acetal (8)
BzO
Ortho ester (5)
AcO
OMe
EtS
SEt
OBz
OBz
OBz
OAllyl
Protected Dithio acetal (9)

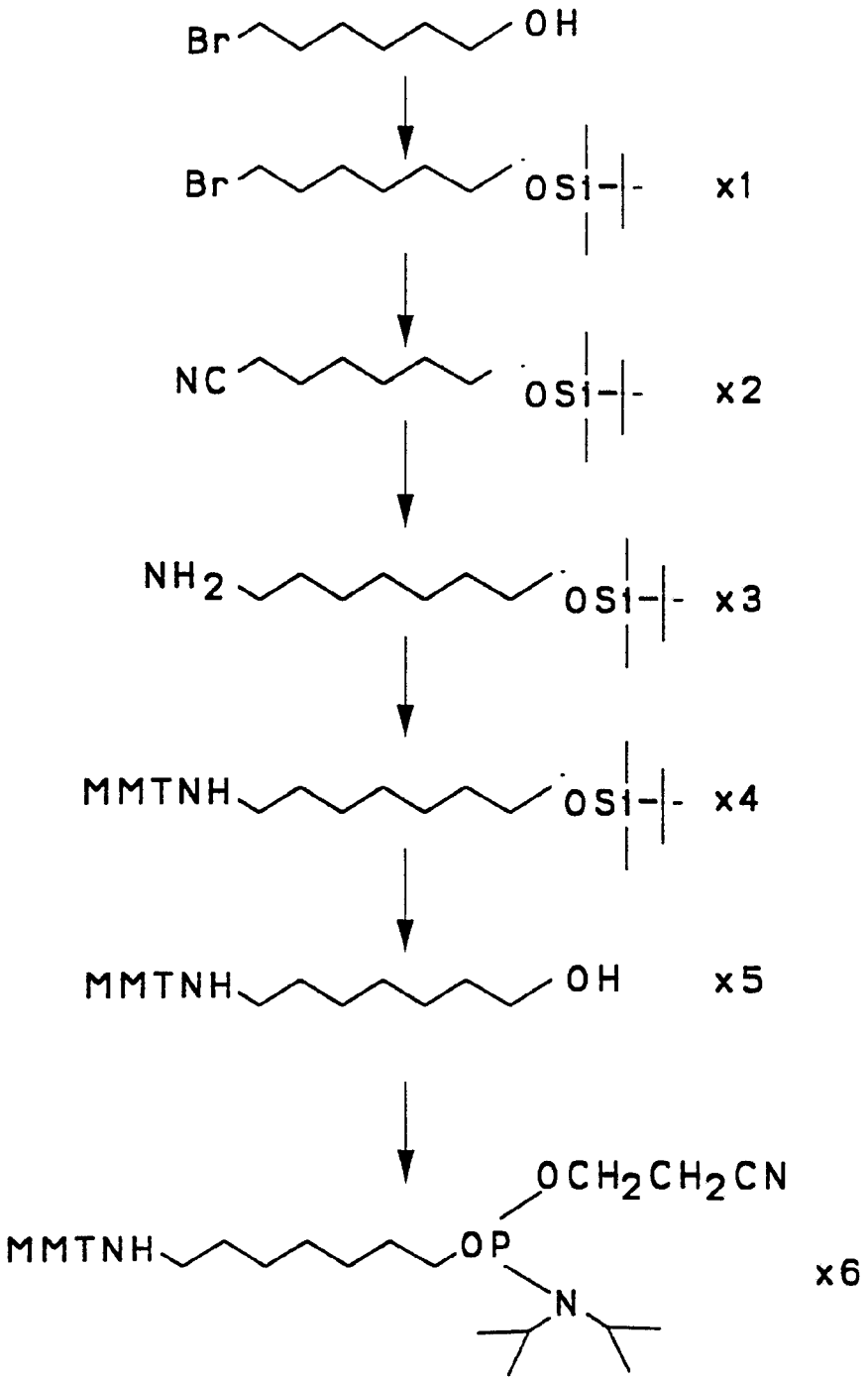
FIG.14A.



(13) R=H, REPEATING UNIT
(14) R=DMT, ANCHORING UNIT

Scheme 1

FIG.14B.



Scheme 2

FIG.14C.

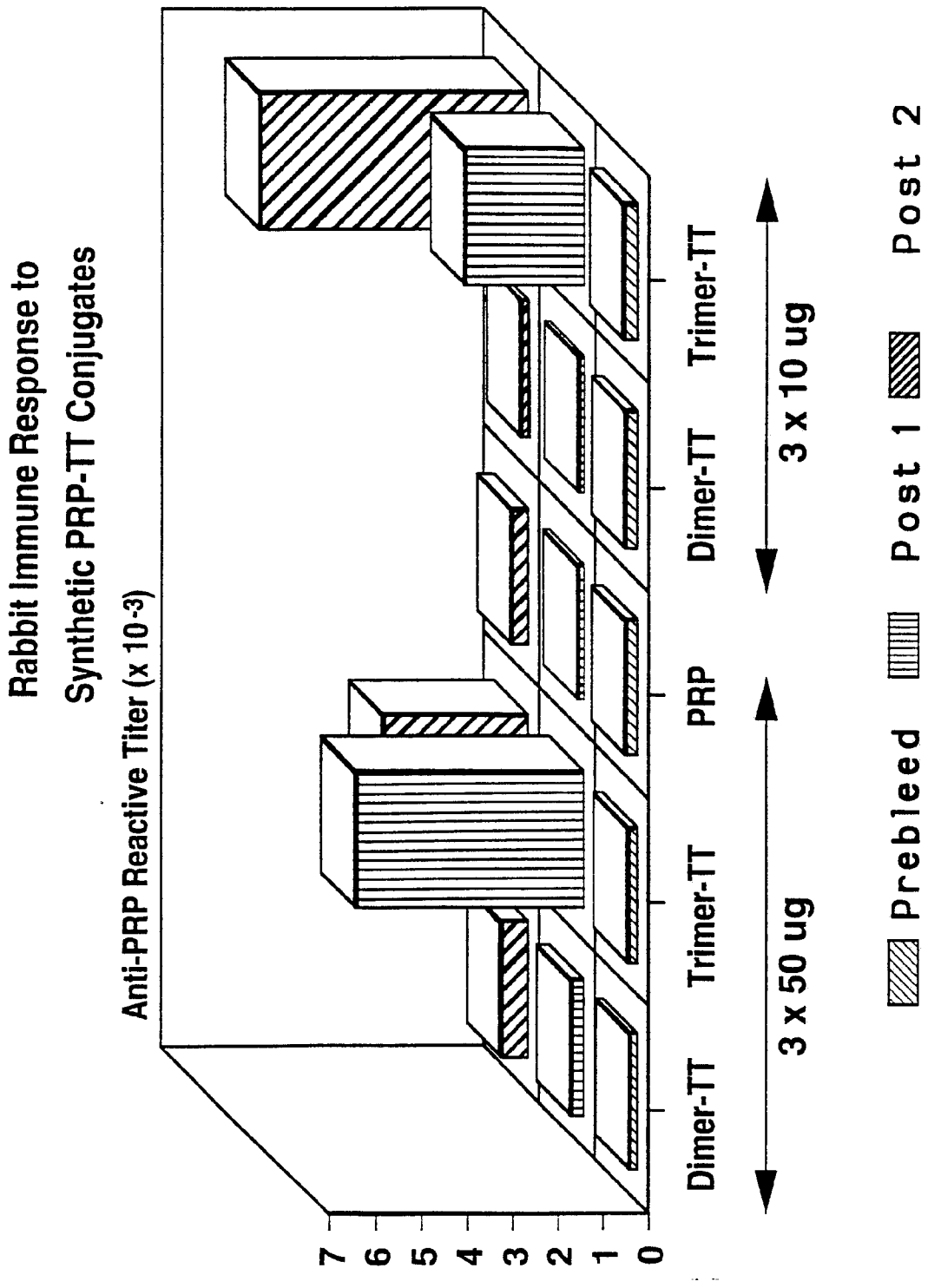

Rabbit Immune Response to
Synthetic PRP-TT Conjugates
Anti-PRP Reactive Titer (x 10-3)
7
6
5
4
3
2
1
0
Dimer-TT
Trimer-TT
PRP
Dimer-TT
Trimer-TT
3 x 50 ug
3 x 10 ug
Prebleed
Post 1
Post 2

FIG.15.

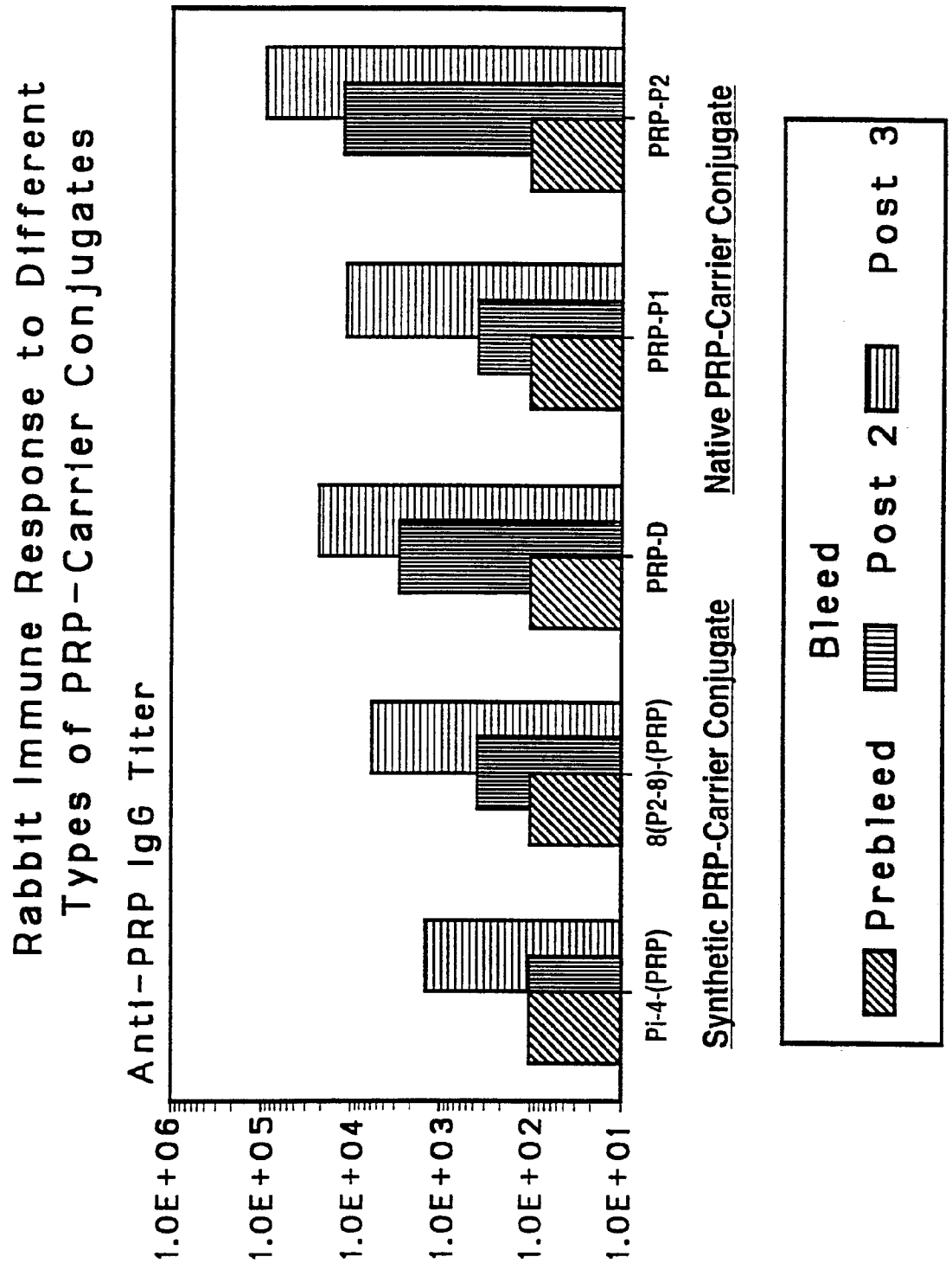

Rabbit Immune Response to Different Types of PRP-Carrier Conjugates
Anti-PRP IgG Titer
1.0E+06
1.0E+05
1.0E+04
1.0E+03
1.0E+02
1.0E+01
Pi-4-(PRP)
8(P2-8)-(PRP)
PRP-D
PRP-P1
PRP-P2
Synthetic PRP-Carrier Conjugate
Native PRP-Carrier Conjugate
Bleed
Prebleed
Post 2
Post 3

FIG.16.

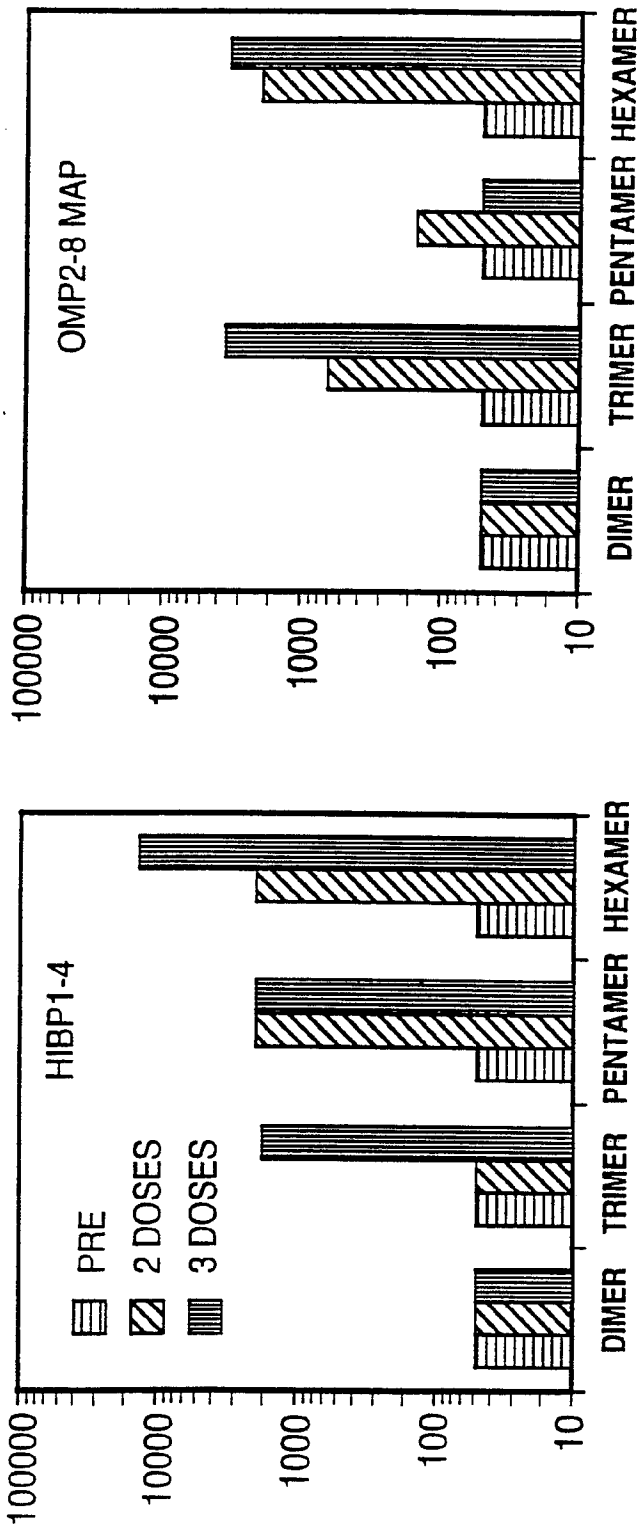

Rabbit Immune Response to Different Synthetic PRP-Peptide Conjugates
HIBP1-4
OMP2-8 MAP
PRE
2 DOSES
3 DOSES
100000
10000
1000
100
10
DIMER
TRIMER
PENTAMER
HEXAMER
ANTI-NATIVE PRP
SYNTHETIC PRP OLIGOMERS

FIG.17.